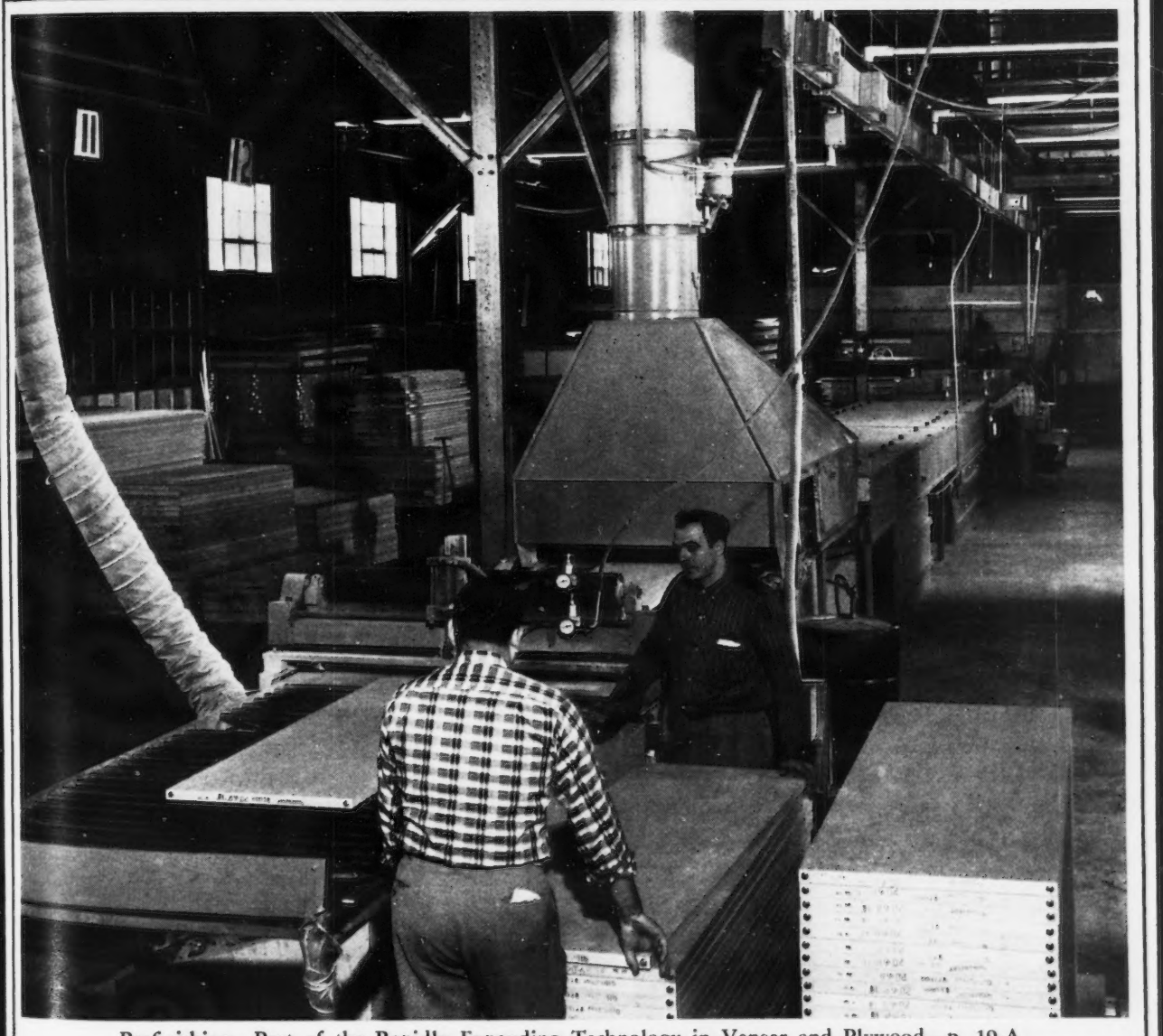
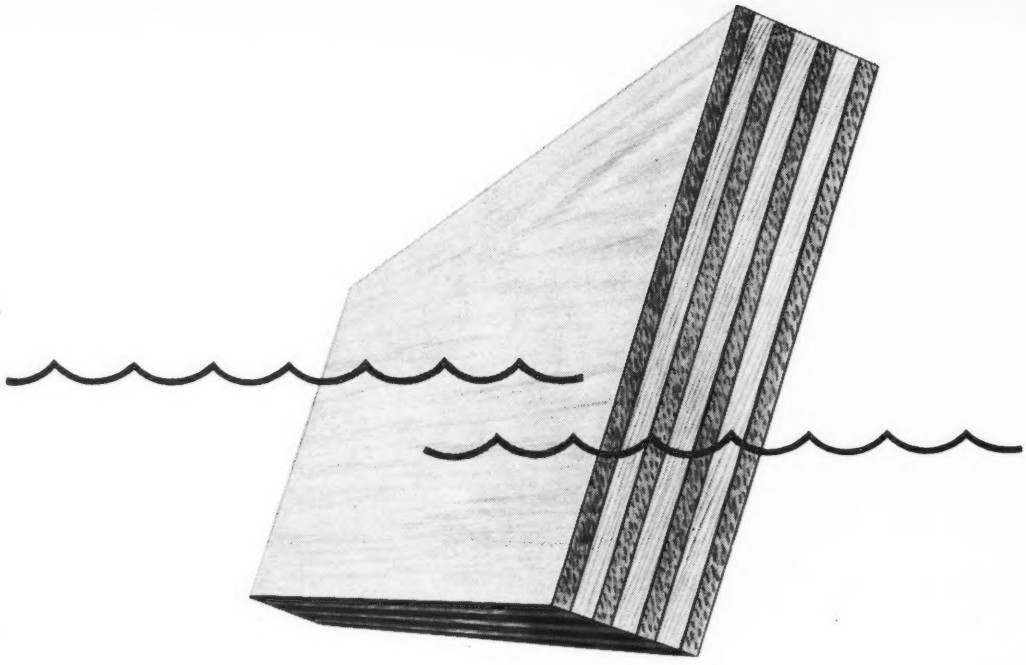
FEATURED THIS ISSUE
VENEER AND PLYWOOD

Forest Products Journal



Prefinishing—Part of the Rapidly Expanding Technology in Veneer and Plywood—p. 19-A.

Published by the FOREST PRODUCTS RESEARCH SOCIETY BOX 2010, MADISON 5, WISCONSIN



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Correspondence on editorial matters should be addressed to the Editor, at the Executive Office. The Society is not responsible for views expressed in publications.

FOREST PRODUCTS JOURNAL

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IMPORTANT FPRS DATES

May 1–2, 1958: Northern California Section Meeting, Berkeley, Calif.

May 5–6, 1958: Pacific Northwest Section Meeting, Seattle, Wash.

May 15–16, 1958: Florida–Georgia–Alabama Section Meeting, Macon, Ga.

Mid-May, 1958: Carolinas–Chesapeake Section Meeting, Winston–Salem, N. C.

June 22–27, 1958: Twelfth National Meeting, Madison, Wis.

Aug. 21–22, 1958: Great Lakes Section Meeting, Houghton, Mich.

Oct., 1958: Joint Pacific Northwest—Inland Empire Section Meeting, Vancouver, B. C.

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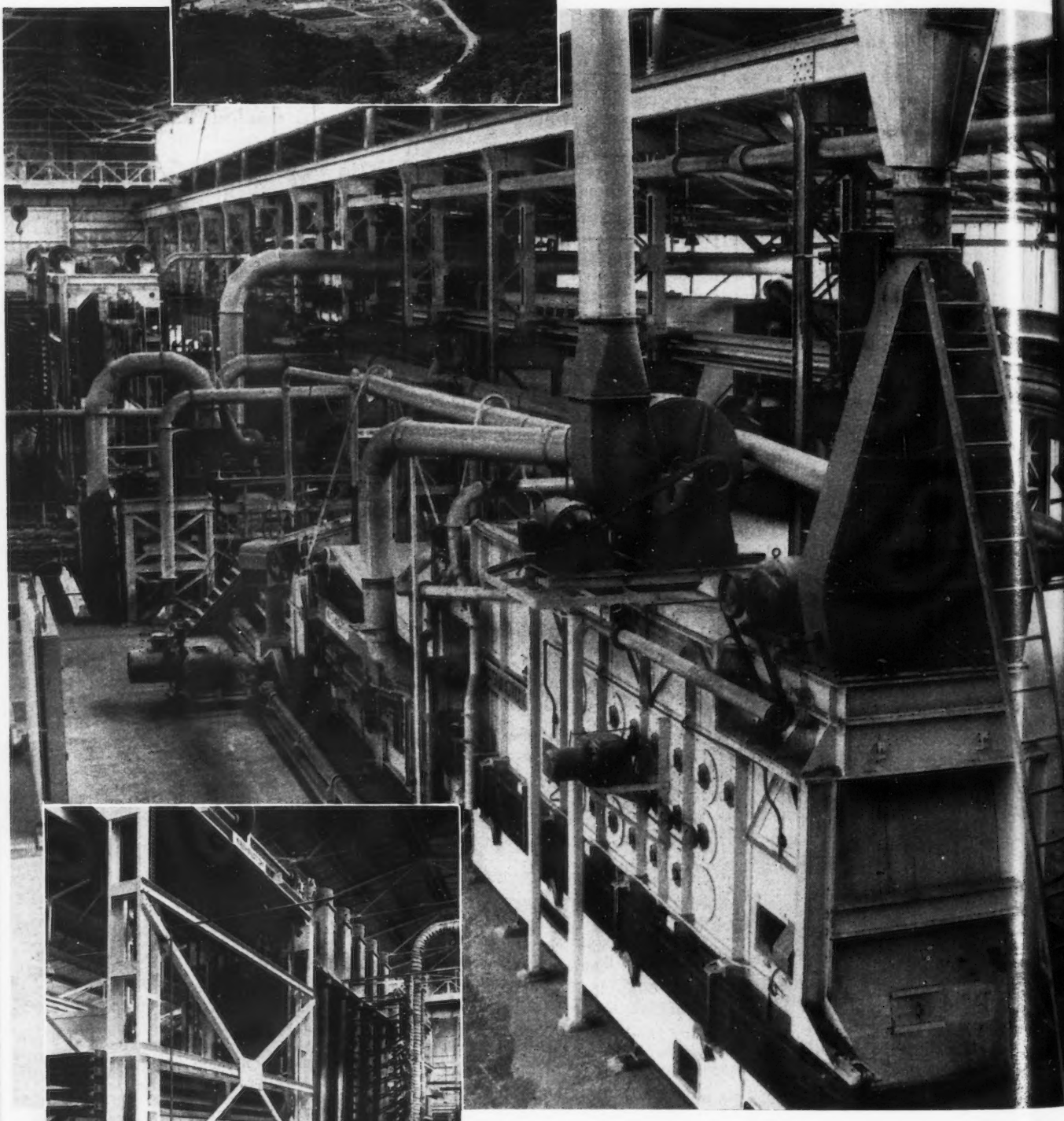
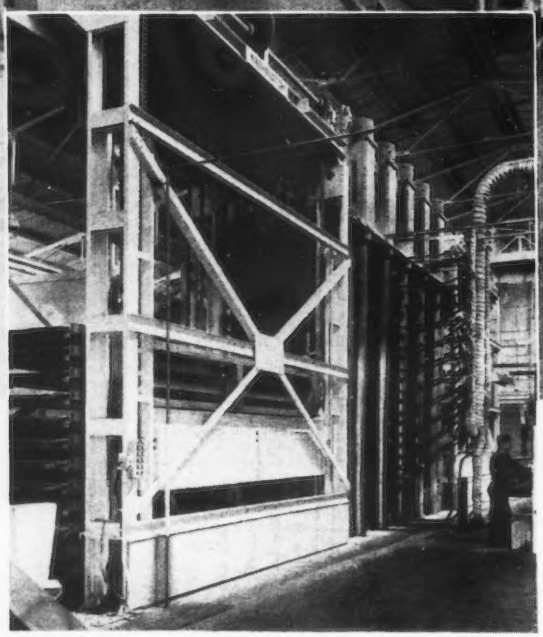




Above photo shows the equipment layout of the forming stage. In the foreground is the felter, behind it the precompressor, trim saws, transfer unit and conveyors. In the background is the 20-opening hot plate press, companion loading and unloading equipment, board separator and caul return line. At left is a closeup of the Washington loader (foreground), 6380-ton press and unloader.

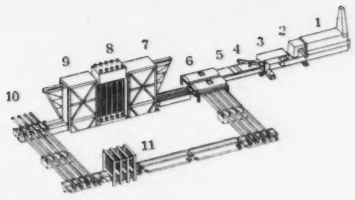
WASHINGTON-BUILT EQUIPMENT

(Australia) Ltd. . .

another Washington-built

press and complete forming line

for dry process hardboard production



1. Felter
2. Shave-off
3. Pre-compressor
4. Flying and trim saws
5. Speed Changer
6. Vacuum transfer
7. Loader and injector
8. 20-opening hot press 6380-ton, 4½′ x 18′
9. Unloader and ejector
10. Board separator
11. Circulating caul system

The Eildon plant of Masonite Corporation (Australia) Ltd. is the first *dry process* hardboard plant of Masonite Corporation or its licensees. Production is planned at the rate of 360,000 square feet per day on a ⅛″ basis. With present facilities, now in commercial production, a smooth-two-sides hardboard in thicknesses from 1/10″ to ½″ can be produced in panels up to 4½′ by 18′, providing a range of thicknesses and sizes hitherto unavailable on the Australian market.

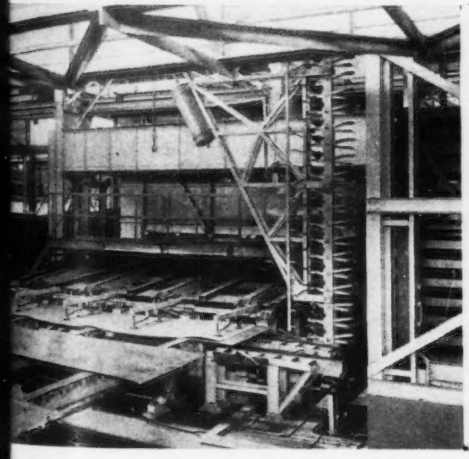
This highly automated plant was planned by the Washington Iron Works, and other suppliers, with Masonite's engineers co-ordinating and laying out the machinery locations.

The services of Washington Iron Works included preliminary planning and final engineering, manufacturing, testing and supervision of assembly and installation, the same services available to any firm interested in custom-built press equipment for automatic operation. Whether for presses and companion loading equipment for plywood or particle board, a complete dry process production line for hardboard, or special bonding or forming presses, it will pay you to contact Washington Iron Works first.

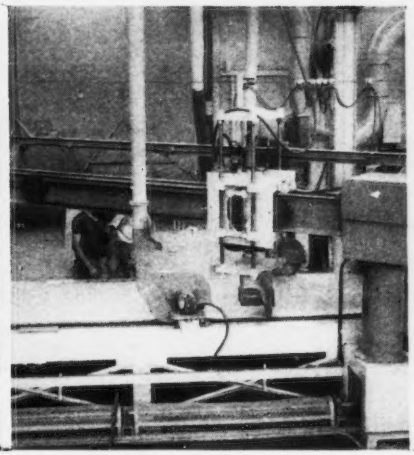
Other hardboard and particle board plants which are using, or have on order, Washington multi-platen press equipment, are:

*Poinsett Lumber & Manufacturing Co., Pickens, S.C. (Subsidiary of Singer Manufacturing Co.)
*Columbia Hardbord Co., Everett, Wash.
*Abitibi Power & Paper Co., Sturgeon Falls, Ont.
*Georgia-Pacific Corp. (Coos Bay Timber Div.) Coos Bay, Ore.
*Timber Engineering Co., Washington, D.C.
*American Parboard Corp., Black Mountain, N.C.
*Carolina Forest Products Inc., Wilmington, N.C.
Johns-Manville Corp., Natchez, Miss.
Gray Products Co., Waverly, Va.
Cuban Bagasse Products S.A., Havanna, Cuba
West Virginia Pulp & Paper Co., Tyrone, Penn.
Kroehler Manufacturing Co., Meridian, Miss.
Daiken Trade & Industries Co., Ltd., Tokyo, Japan

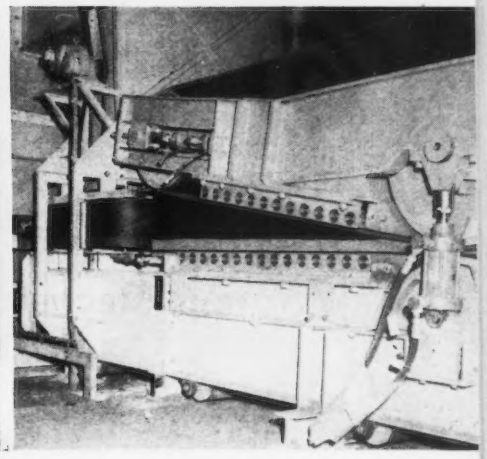
*A new 16-page brochure "Washington presses and accessory equipment" features case history data and photos of these plants in operation, along with Masonite and other users of Washington presses. Your copy is available FREE by writing to Washington Iron Works.



The Washington board separator lifts finished boards from caul plates as they are removed by the ejector from the elevator-type unloader. The boards are flipped over to conveyor (background). The empty cauls on the return conveyor line (foreground) are returned to the forming line.



As the formed mat leaves the precompressor on a conveyor belt, the side trim saws and flying saws automatically cut the mat to predetermined width and length, ready for the press. Maximum panel size is 4½′ x 18′.



The thick blanket of wood fibers, formed on the conveyor belt in the felter unit, is compressed by the precompressor to a homogeneous mat, prior to being trimmed and cured. Large pinch rolls exert a 30,000 lb. pressure. Holding rolls maintain 10 psi.

WASHINGTON presses and accessory equipment

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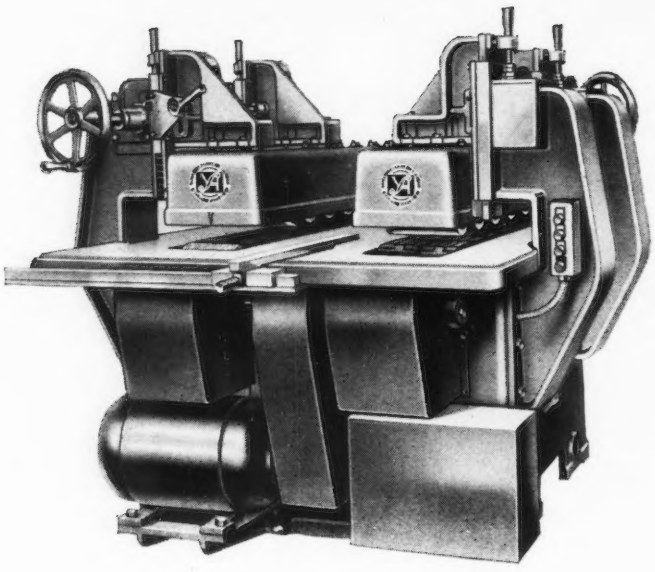

Yates-American presents a unique, chain-feed, double rip saw, the "**TWINRIP**." A "**TWINRIP**" can double the production of any single rip, two-man-operated saw. Feed Rates: up to 600 fpm., triple capacity of a single saw. Saw Speeds: up to 7,200 rpm., twice the speed of a single rip. Handles stock up to 23" wide through both saws simultaneously. Blades operate in tandem or feed from both directions, merry-go-round style. Thinner carbide blades save up to 3/64" kerf on each rip. "**TWINRIP**" space requirement: only 10'x10'. Write for technical catalog.

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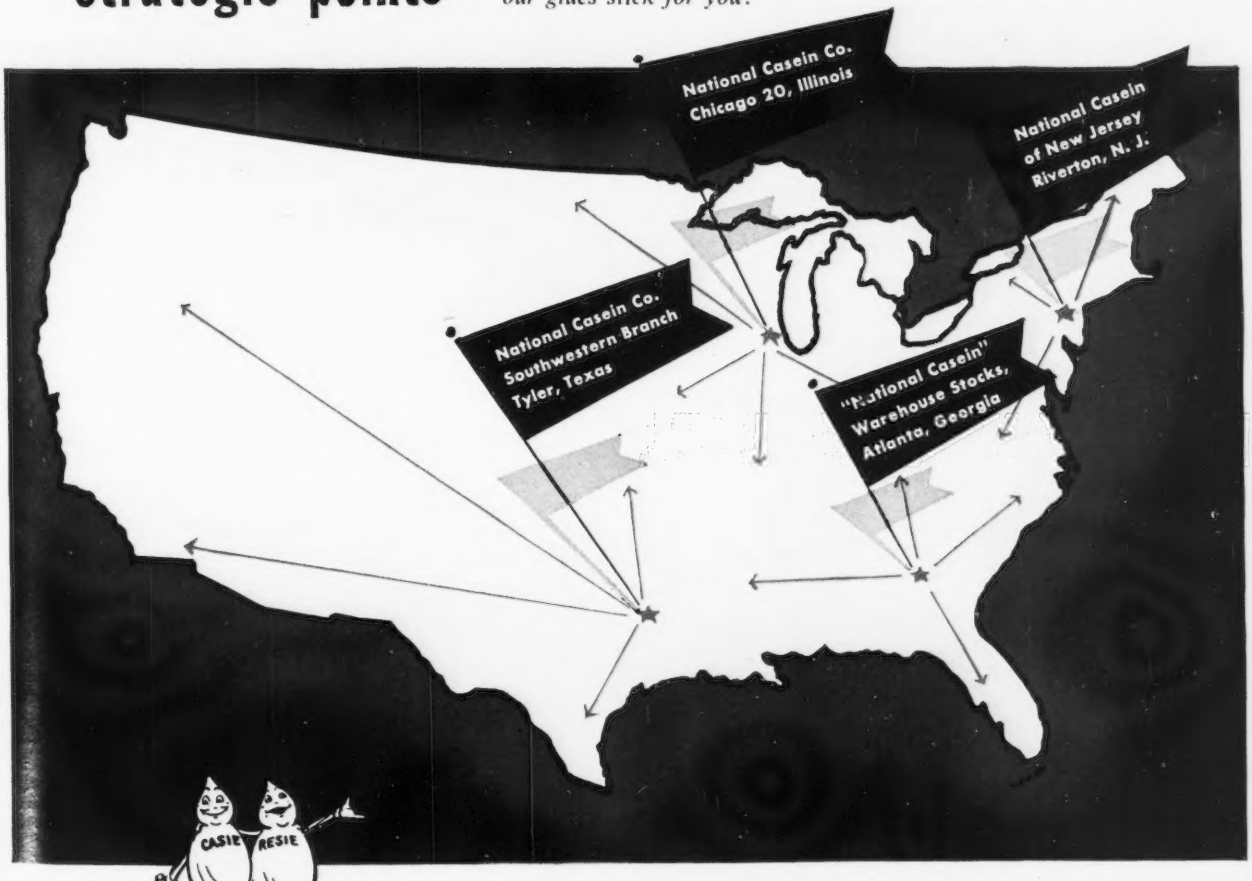

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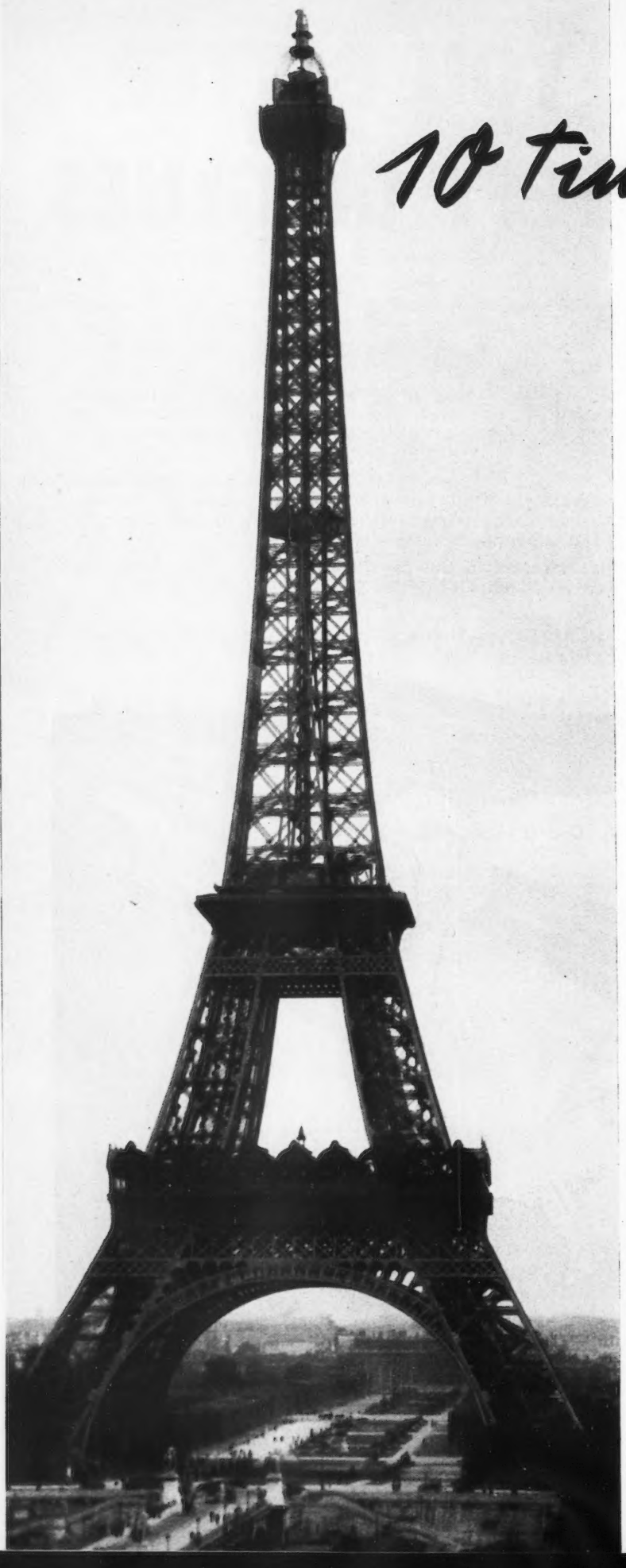

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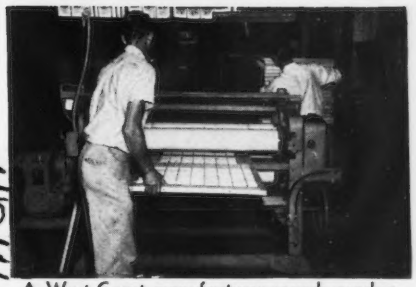
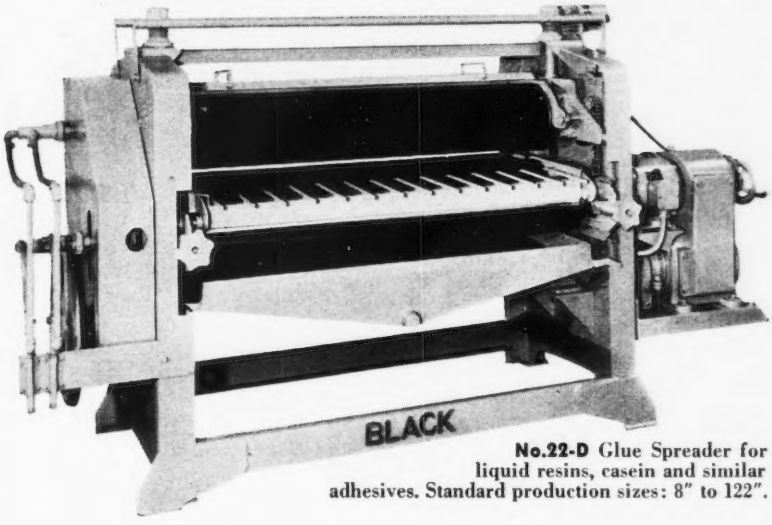


A West Coast manufacturer speeds production of hollow core flush doors with the No. 22-D, 50".

Brilliant New Successes in Gluing and Laminating

For glue testing and development work, a leading glue manufacturer depends on the No. 22-D Spreader.



No.22-D Glue Spreader for liquid resins, casein and similar adhesives. Standard production sizes: 8" to 122".

Versatile No. 22-D Spreader helps produce laminated beams and roof trusses at a California mill.

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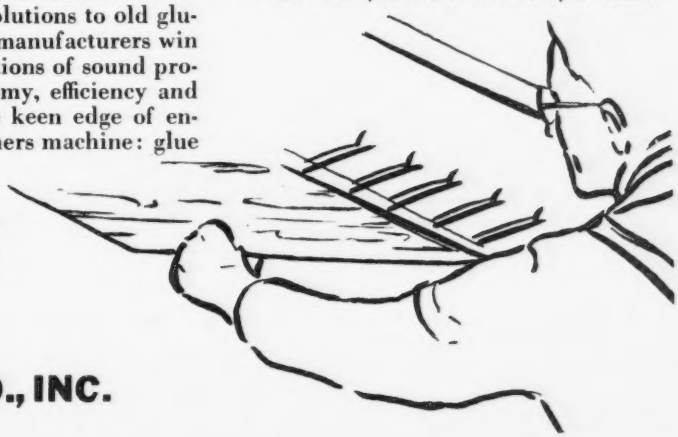

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FPRS NEWS-DIGEST

Volume VIII APRIL, 1958 Number 4

List of Technical Papers Grows for FPRS Nat'l Meeting, June 22-27

More than 50 papers have been confirmed for the FPRS National Meeting in Madison, June 22–27, and additional papers are expected to be confirmed in the next few weeks, W. Jeter Eason, Program Chairman for the meeting reports. A total of 16 sessions are planned.

V. L. HARPER

The keynote session this year has as its theme "Insurance for the Future —Through Forest Products Research". Speakers at this session will include V. L. Harper, Ass't Chief, Forest Service, U. S. Dept. of Agriculture, Washington, D. C.; Winton Patnode, Director of Research & Development, Weyerhaeuser Timber Co., Tacoma, Wash.; and E. C. Jahn, College of Forestry, State University of N. Y., Syracuse. The Charles J. Williams Memorial Seasoning Lecture will also be presented at this session.

The following papers have been confirmed by the authors. Complete program details will be announced in the May issue of the JOURNAL.

Wood Machining—Mon. am

New Developments on Matchers and Sanders—Yates-American Machine Co.

New Developments in Planers—Buss Machine Works.

Presses and Clamps—Robert Gilbertson, Bell Machine Works, Oshkosh, Wis.

Rip Saws and Moulders—Gustaf A. Johnson, Mattison Machine Works, Rockford, Ill.

Shapers & Routers—John Karlovitz, Chief Engr., Woodworking Machinery Division, Onsrud Machine Works.

Tenoners & Boring—Greenlee Bros. and Co.

Keynote Session—Mon. pm

Federal Research — V. L. Harper, Ass't Chief, Forest Service, U. S. Dept. of Agriculture, Washington, D. C.

Industry Research — Winton Patnode, Director of Research & Development, Weyerhaeuser Timber Co., Tacoma 1, Wash.

Educational Institution Research—E. C. Jahn, College of Forestry, State University of New York, Syracuse.

Highlights in the Development of Kiln Drying—Harry D. Tiemann, retired specialist on seasoning from the U. S. Forest Products Lab., Madison, Wis.

Veneer and Plywood—Tues. am

The Effect of High Temperatures on the Strength of Douglas-fir Veneer—P. L. Northcott, Forest Products Laboratories of Canada, Vancouver, B. C.

Wood Preservation—Tues. am

Can We Preserve Our Wood Markets—C. H. Hoffman, Koppers Co., Inc., Pittsburgh, Pa.

Preservative–Water Repellent Treatments for Wooden Packing Boxes—Dr. A. F. Verrall, Chief of Forest Disease Research, Southern Forest Experiment Station, New Orleans, La.

History and Development of Wood Preservation for Millwork in the United States—C. Ormie Lance, Secretary–manager, Nat'l Woodwork Mfrs. Assoc., Chicago, Ill.

Improving Wood's Durability through Chemical Modification—R. H. Baechler, U. S. Forest Products Laboratory, Madison, Wis.

Preservation of Particle Board—Henry A. Huber, Dow Chemical Co., Midland, Mich.

Industry–Education—Tues. am

Training for Research and Development Work for the Wood Industries—B. A. Jayne, Yale School of Forestry, New Haven, Conn., and R. W. Wellwood, University of British Columbia, Vancouver, B. C., Canada

A New Look at the Undergraduate Curriculum in Forest Products—D. B. Richards, John Hill, and Wilbur DeVall, Alabama Polytechnic Institute, Auburn, Ala.

Logging—Tues. pm

Radio—Essential Tool of Forestry—Robert W. Olin, Director of Planning, Potlatch Forests, Inc., Lewiston, Idaho.

Integrated Hardwood Logging—C. E. Hein, Chief Forester, Goodman Lumber Division, Calumet & Hecla, Inc., Calumet, Mich.

Possible Uses of Helicopters in Logging—Panel Discussion. J. G. Townsend, Mgr., Helicopter Division, Spartan Air Service Ltd. Ottawa, Ont., Can.; Carl Agar, vice-pres., Okanagan Helicopters Ltd., Vancouver Airport, B. C., Can.; and Cal Ferris, Director, Air Operations, U. S. Forest Service, San Francisco, Calif.

Glues and Gluing—Tues. pm

Exterior Weathering Studies of Fortified Urea–Resin Glues—R. F. Blomquist and W. Z. Olson, U. S. Forest Products Laboratory, Madison, Wis.

Thermosetting Adhesives from Bark Extracts—Dr. L. H. Bock and Associates, Olympic Research Division, Rayonier, Inc., Shelton, Wash.

Surface Properties of Wood as Related to Joint Strength—J. E. Marian, University of California, Forest Products Laboratory, Richmond.

Industry Uses of an Automatic Machine for the Rapid Evaluation of Plywood Glue Bonds—B. S. Bryant, University of Washington College of Forestry, Seattle.

Quality Control—Tues. pm

Organization of a Quality Control Program—Ross Martin, Sears, Roebuck & Co., Chicago, Ill.

Elementary Statistical Quality Control Charts—Edward R. Hansen, Hamilton Mfg. Co., Two Rivers, Wis.

Statistical Quality Control in Logging Cost Control—L. J. Lussier, North Shore Paper Co., Can.

Statistical Control of Grade Yields of Lumber from Hardwood Logs—A. C. Barefoot, and R. M. Carter, North Carolina State College, Raleigh.

Cost Reduction Through Methods Improvement—George Vasiliou, Cleveland, Ohio.

Wood Drying—Wed. pm

Factors Influencing the Permeability of Softwood During Impregnation and Drying—John P. Krier, School of Forestry, Montana State University, Missoula.

Factors Associated with the Development of Collapse During Kiln Drying of Aspen Lumber—Dr. Arne Kemp, Head, Dept. of Forestry, Stephen F. Austin State College, Nacagdoches, Texas.

Some Aspects of Drying Wood at Temperatures Above 100° C.—Prof. John L. Hill, Alabama Polytechnic Institute, Auburn.

Air Drying of 4/4 Red Oak Flooring Stock in Southern Wisconsin—Edward C. Peck, U. S. Forest Products Laboratory, Madison, Wis.

Roof your Lumber and Increase Your Profits — Wendell Clark and Thomas M. Headlee, Carbondale Forest Research Center, Central States Forest Experiment Station, Carbondale, Illinois.

Air Drying Western Softwoods with Forced Air Circulation—Jack R. Pfeiffer, Oregon Forest Products Research Center, Corvallis.

Operation Predry—Variables in Drying Southern Pine—Louis I. Gaby, Athens-Macon Research Center, Southeastern Forest Experiment Station, Athens, Ga.

Wood Finishing—Wed. pm

A New Tool for Measuring the Adhesion of Surface Coatings to Wood Products—Bruce O. Halbert, Weyerhaeuser Timber Co., Longview, Washington.

Steineman Machine for Flow Coat Application of Lacquers, Synthetics, Polyesters—E. Sigurd Johnson.

Surface Treatment of Wood Preparatory to Finishing—Armin Elmendorf, Elmendorf Research Inc., Palo Alto, Calif.

The Prefinishing of Plywood with a Vinyl Overlay—W. Jeter Eason, vice president, Nickey Bros., Inc., Memphis, Tenn.

Chemical Utilization—Wed. pm & Thurs. am

The Production of Torula Yeast from Spent Sulfite Liquor—Jess Holderby, vice president, Lake States Yeast Corp., Rhinelander, Wis.

Microbiological Utilization of Wood Sugars—George Hajny, U. S. Forest Products Laboratory, Madison, Wis.

Alcohol Production from Spent Sulfite Liquor—Carter A. Watson, Technical Director, Puget Sound Pulp & Timber Co., Bellingham, Wash.

The Value of Wood Waste in Promoting Plant Growth—Steward Dunn and Judith D. Emery, Agricultural Experiment Station, Durham, N. H.

Fermentative Action of Isolated Rumen Organisms on Wood Substrates—Don Stranks, Forest Products Laboratories of Canada, Ottawa, Ont.

Preparation and Uses of Sawdust Compost—Prof. Sergius S. Wilde, University of Wisconsin, Madison.

By-Product Utilization from Sulfite Pulping—J. R. Salvesen, Marathon Division, American Can Co., Rothschild, Wis.

Technical and Economic Aspects of Furfural Production from Hardwood—Frederick G. Perry, Jr., Joseph J. Voci, and R. Claire Canty, Arthur D. Little, Inc., Cambridge, Mass.

Newer Activities of National Council for Stream Improvements Re: Air Pollution—Russell O. Blosser, Kalamazoo College, Kalamazoo, Mich.

Steam Pollution Control Activities in Wisconsin—Theodore F. Wisniewski, Director, Wisconsin Commission on Water Pollution, Madison.

Charcoal Briquetting — Paul D. Haigh, vice president, Komarek-Greaves & Co., Chicago, Ill.

General—Thurs. am

How to Build Better Wood Houses with Today's Materials—John Rex, Pacific Lumber Co., Chicago, Ill.

Commercial Possibilities of Forests of the Amazon Region — Llewelyn Williams, Randolph, Wis.

Diffusion of Bound Water through Wood Substance—Dr. A. J. Stamm, U. S. Forest Products Laboratory, Madison, Wis.

The Challenge of the Overhead Door—Ralph Casselman, Engineering Products & Service Co., Washington, N. J.

An Electron Microscopic Investigation of Pit Membrane Structure in Conifers and Hardwoods.

PRE-REGISTRATION FORM

TWELFTH ANNUAL MEETING—FOREST PRODUCTS RESEARCH SOCIETY
MADISON, WISCONSIN JUNE 22–27, 1958

Return to: Forest Products Research Society, P.O. Box 2010, University Station, Madison 5, Wisconsin

Name _____
Last First Middle Mrs.

Address _____

City _____ State _____

Company or Organization _____

REGISTRATION (Including transportation to Forest Products Laboratory and return)

		Enter Amounts Below
FPRS Member	$ 7.00	$_____
Non-Member	10.00	$_____
Ladies	5.00	$_____
Children Name _____ Age_____		
n/c Name _____ Age_____		
FPRS Official Luncheon, per ticket	3.00	$_____
FPRS Banquet and Paul Bunyan Hour, per ticket	7.00	$_____
Total Enclosed		$_____

Allis–Chalmers Co., Milwaukee, Wis.

Kimberly–Clark Corp. bookpaper mill, Kimberly, Wis.

Seven Open-House Tours Planned for June 27

A choice of scheduled open-house tours will be available for FPRS registrants to visit in connection with the Society's annual meeting in Madison this June, Wayne C. Lewis, chairman of the up-state plant tour program, announced recently. Friday, June 27, has been set aside as the day for these visits to take place.

Plant as well as research facilities will be featured in some of the visits, and the choice of tours will vary from pulp and paper operations to the production of musical organs and prefabricated homes. A registration desk to sign up for these tours will be staffed at the Hotel Loraine, meeting headquarters.

Tour Highlights

Allis–Chalmers Mfg. Co., Milwaukee, Wis. The tour will include one of the largest machinery erection floors and other modern tractor and equipment facilities. Mr. Clint Busacca will lead visitors on the tour. The firm is Wisconsin's largest industrial organization with over 25,000 employees. Allis–Chalmers manufactures wheel and crawler type tractors and hydraulic debarkers, electric power and mechanical transmission equipment.

Hammond Organ Co., Chicago, Ill. The tour will include the firm's wood laboratory, cabinet plant, and rubbing and final assembly of the organs. These features will be shown at three of the firm's Chicago plants. A major part of Hammond's woodworking needs are supplied in home plants and some by sub-contractors. Hammond produces the home, church, and concert variety of organ, and Chord organ. Major woods used in manufacturing the consoles are walnut, cherry, and oak.

Harnischfeger Homes, Inc., Port Washington, Wis. The production of prefabricated house parts will be shown in the tour of Harnischfeger plant. A subdivision of model prefabricated homes produced by the firm and adjacent to the plant will also be shown.

The Institute of Paper Chemistry, Appleton, Wis. The chemistry laboratory, pulp laboratory, and other major facilities of the research institute will be shown. The major private research organization of the United States pulp and paper industry, the Institute is also affiliated with Lawrence College, and issues advanced degrees in cooperation with the college. Fundamental and applied research are conducted by staff members who are financed through institutional funds. Cooperative research, specific projects undertaken on a nonprofit financial basis on behalf of either individual companies or a group of companies, is also carried out.

Kimberly-Clark Corp., Neenah, Wis. The tour will show the Lakeview Mill at Neenah, or the Kimberly, Wis.

Kimberly–Clark Corp. Lakeview Division of Neenah mill.

Mosinee Paper Mills, Mosinee, Wis.

The Institute of Paper Chemistry, Appleton, Wis.

Marathon Corp. Research Laboratory, Rothschild, Wis.

Prefabricated panels at Harnischfeger Homes Inc., Port Washington, Wis.

mill. Also to be visited are the Research and Development Laboratories of the Corp. At the Neenah mill mainly the production of mainly consumer products can be seen, such as Kleenex. One of the main products of the Kimberly mill is book paper. One or the other of the mills will be shown to visitors, not both.

Marathon Corp., Rothschild, Wis. The Rothschild plant will be shown on the tour, and will include the sulfite and paper mill with the chemical by-products operations. The research laboratories, which are well known for developments in lignin research and utilization, will also be shown to visitors.

Mosinee Paper Mills, Mosinee, Wis. Visitors will be shown the production facilities and technical departments of the Mosinee plant. Seen during the tour will be the facilities that produce some of the Mosinee industrial papers. Mosinee produces sulphite pulp and paper as well as abrasive backing, electrical papers, asphalt laminating papers, automotive drip shield paper, water-repellent papers, and many others.

Allis–Chalmers Testing Floor

Shaping operation at Hammond Organ Co.

Hammond Organ plant, Chicago, Ill.

Pulp Laboratory at the Institute of Paper Chemistry

No. 5 Paper Machine at Kimberly–Clark bookpaper plant.

A Marathon chemical from spent sulfite liquor sacked at a spray dryer.

Student Employment by Industry Urged by Placement Chairman

N. A. NORTON

"Summer employment should be considered an extension of the student's educational program—an extension only industry can give", Dr. Newell A. Norton stated in a recent letter to the FPS Executive Office

In discussing the Society's employment service for summer and permanent placement, Dr. Norton, chairman of the Employment Service committee, reported that every effort is being made to build up an adequate group of industrial cooperators for the program. A major problem concerns early commitment dates for employment

Students whose summer work helps them to finance their college education usually wish to be placed in jobs by early spring, Dr. Norton said. In many cases, industries are reluctant to commit themselves until late spring when business conditions can be estimated with greater accuracy. In time, Dr. Norton believes this problem will be resolved.

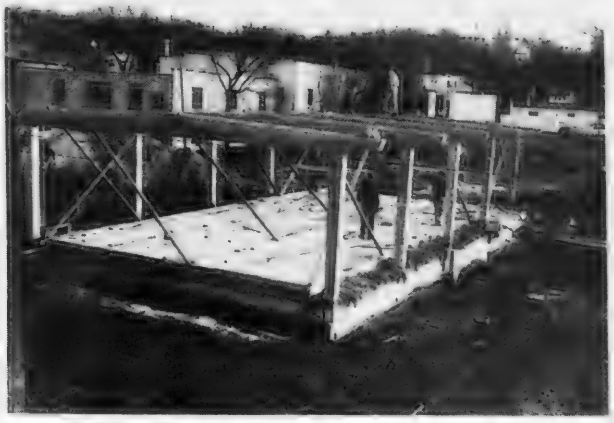
"Participation in the Summer Placement Program is an investment in the future of the industry that will pay good dividends", Dr. Norton said. "The only way that these young men can gain any industrial experience prior to graduation", he went on to say, "is through summer employment. It also gives industry a chance to evaluate these students as possible future employees".

The program, now in its third year, has 36 schools and 45 firms indicating the desire to cooperate in this year's program. Dr. Norton urges firms and instituions who wish to cooperate in the placement program to write him or other members of his committee immediately.

The addresses are: Dr. Newell A. Norton, Dept. of Forestry, Penn. State University, University Park, Pa.; E. A. Behr, Chapman Chemical Co., Malby Sta., Box 3158, Memphis, Tenn.; R. W. Petterson, RFD 2, Box 46A, Gig Harbor, Wash.; R. N. Carter, School of Forestry, N. C. State College, Raleigh, N. C.; H. H. Smith, P. O. Box 245, Berkeley 4, Calif.; and E. W. Stark, Dept. of Forestry, Purdue University, Lafayette, Ind. Queries can also be addressed to the executive office.

Photo Progress Report — Monthly Growth of the FPRS Office Building

Beginning of laminated post and beam construction is shown above. At right is the completed post and beam construction.



Laminated posts and beams were donated by United Structures, Inc., and Rilco Laminated Products Inc.

Stacked roof decking contributed by the Tahoe Timber Co.

Of tongue and groove variety, the white fir 4 by 5 inch decking is nailed by workmen.

Offices are laid out with interior framing lumber, all donated by Peshastin Lumber & Box Inc.

Built up 2 inch insulation board is nailed over roof decking. M & O Paper Co., and Wood Conversion Co. furnished the insulation board.

Outline of the Executive Office Building takes shape as workmen concentrate on roofing to protect interior of the structure. The building will be the culmination of the Society's efforts over the past several years to establish a permanent headquarters. The finished structure will include many forest products improved or developed through continuing research.

Four layers of Koppers Co. roofing paper and tar were used (left) to seal the decking and insulation from the weather.

Industry Suppliers Will Host Paul Bunyan Social Hour at National Meeting

L. J. FITZPATRICK

Thirty-seven firms supplying materials and services to the wood industry have contributed $50 each as sponsors for the Paul Bunyan Social hour of the FPRS 12th National Meeting, June 22–27, according to L. J. Fitzpatrick, chairman for the event.

Sponsoring firms will be hosts to meeting registrants and their families at the social hour preceding the Official FPRS Party and Banquet, June 25, at the Maple Bluff Country Club.

Firms interested in assisting as sponsors of this event are invited to write to Mr. L. J. Fitzpatrick, J. J. Fitzpatrick Lumber Co., Madison, Wis.

The sponsors as of March 31 are:

Algoma Division, U. S. Plywood Corp., Algoma, Wis.
American Cyanamid Co., New York, N. Y.
American Mfg. Co., Tacoma, Wash.
American-Marietta Co., Seattle, Wash.
Arnold Dryer Co., Milwaukee, Wis.
The Bahnson Co., Winston-Salem, N. C.
Bauer Bros. Co., Springfield, Ohio.
The Black Bros. Co., Inc., Mendota, Ill.
The Borden Co., New York, N. Y.
The Carborundum Co., Niagara Falls, N. Y.
The Coe Mfg. Co., Painesville, Ohio.
Peter Cooper Corps., Gowanda, N. Y.
Diamond Gardner Corp., Chico, Calif.
Disston Division, H. K. Porter Co., Philadelphia, Pa.
The Dow Chemical Co., Midland, Mich.
Green Bay Paper & Pulp Co., Green Bay, Wis.
Durez Plastics Division, Hooker Electrochemical Co., North Tonawanda, N. Y.
Hitchcock Publishing Co., Wheaton, Ill.
Industrial Woodworking, Cleworth Publ. Co., Cos Cob, Conn.
Koppers Co., Inc., Pittsburgh, Pa.
The Lilly Co., High Point, N. C.
Masonite Corp., Chicago, Ill.
Mattison-Greenlee Service Corp., Rockford, Ill.
Merritt-Solem Division, Solem Machine Co., Lockport, N. Y.
Moore Dry Kiln Co., Jacksonville, Fla.
National Casein Co., Chicago, Ill.
Nelsonite Chemical Products, Inc., Grand Rapids, Mich.
Pacific Lumber Co., Chicago, Ill.
Perkins Glue Co., Lansdale, Pa.
Protection Products Mfg. Co., Kalamazoo, Mich.
Simonds Saw & Steel Co., Leominster, Mass.
Solem Machine Co., Rockford, Ill.
Southern Screw Co., Statesville, N. C.
Synvar Corp., Wilmington, Del.
United States Plywood Corp., New York, N. Y.
Weyerhaeuser Timber Co., Tacoma, Wash.
Williams Patent Crusher & Pulverizer Co., St. Louis, Mo.

Alegretti, Trinkle to Run for Executive Board Post

J. J. ALLEGRETTI

C. TRINKLE

Candidates for North-Central Regional Executive Board Member, a position that will be vacated this June by Robert L. Hiller, American Cyanamid Co., have been announced by Gardner Garlick, chairman of the nominating committee. Nominees are: J. J. Allegretti, Masonite Corp., Chicago, Ill., and Carl Trinkle, Baldwin Piano Co., Cincinnati, Ohio.

Mr. Allegretti is director of product development and market research at Masonite, and holds a BS in forestry from the University of Idaho. He is a past chairman of the Mid-West Section, and one of the organizers of the Upper Mississippi Valley Section.

Dr. Trinkle is chief chemist and head of the material standards department at Baldwin. He is a graduate of the University of Cincinnati, and one of the organizers of the Ohio Valley Section. He is also a past chairman of the Ohio Valley Section.

Dickinson Nominated for Southwest Board Position

F. E. DICKINSON

Fred E. Dickinson was nominated for Southwest Regional Executive Board Member, according to Homer N. Stephenson chairman of the region's nominating committee.

Director of the University of Calif Forest Products Laboratory at Richmond, Mr. Dickinson holds a Ph. D. from Yale University, and is a past chairman of the Northeast Section. He was a judge in the 1957 Wood Award Competition. Dickenson was associated with the U. S. Forest Service and taught at several colleges and universities before accepting his present position. R. H. Berry is the outgoing Board Member.

Water Ballet Engaged for Official Party and Banquet

A professional water ballet company has been engaged as the main entertainment feature of the FPRS National Meeting, T. Walter Noble, chairman of the food and social committee, reported recently. The performance will be given at the Official FPRS Party and Banquet, June 25, at the Maple Bluff Country Club.

Called the Dona Runge Water Ballet and produced by Burmek Theatrical Productions, Milwaukee, the costumed 17-person company will perform comedy and style diving in addition to rhythmic swimming. The hour and three quarter show will be staged under colored lights at the country club's pool as guests enjoy the performance from the terrace.

Bark Utilization Subject of Northern California Meeting Planned May 1–2 at Berkeley

Bark utilization is the theme of the May 1 and 2 meeting of the Northern California Section, to be held at the Claremont Hotel, Berkeley, Calif. Main speaker at the official dinner will be R. W. Hess, Director of Research, Georgia-Pacific Corp., who will talk on Personnel Recruitment.

"Yield and Preparation of Bark from a Medium-Sized Sawmill" will be the topic of a talk by E. P. Ivory, Ivory Forest Products, at the first technical session. He will be followed by Dr. Nicholas Poleticka, Union Lumber Co., who will speak on "Bark Recovery, Yields, and Preparation in the Redwood Region". "Milling of Redwood Bark" will be discussed by J. H. Wright, The Bauer Bros. Co.

Prof. H. C. Kohl, University of California will open the second technical session with a paper on "Use of Bark for Soil Improvement". "Commercial Aspects of Growing Orchids in Fir Bark" will be the subect of a paper by R. McClellan, of The Rod McClellan Co. E. Burton, of the Ed Burton Co., will speak on "Bark as a Trickle Filter Media".

The Friday morning technical session will begin with a paper on "Chemicals from Bark" presented by Dr. Eduard Farber, Timber Engineering Co. "Use of Bark in Hardboards" will be discussed by Arthur B. Anderson, University of Calif. Forest Products Laboratory, and R. W. Miller, the Pacific Lumber Co., will speak on "Bark's Other Uses".

H. A. Brune, a Berkeley architect, will act as chairman for the last session. D. F. Laughnan, U. S. Forest Products Laboratory, will speak on "Wood's Effect on Finish Durability". "Problems in Exterior Finishes on Woods" will be discussed by Neil Estrada, Reichhold Chemical Co., and the last paper on "Attempts to Modify the Effect of Weather on Redwood by Stabilizing the Color of Water-Repellent Treatment", will be presented by W. A. Dost, Calif. Redwood Assoc.

5,000 to See National Woodworking Machinery Show, May 13-17

C. DuBRUCQ

One hundred and five exhibitors have reserved all of the available space for the American Woodworking Machinery & Equipment Show, May 13–17, in Winston-Salem, N. C., show manager D. O. Warner announced recently.

Cooperating closely in administration of the event are, Ray DuBrucq, president, Woodworking Machinery Mfgs. Assoc., and J. T. Ryan, executive vice-president, Southern Furniture Mfgs. Assoc., representatives of the show's sponsoring organizations.

Cooks Warehouse, a structure 173 feet wide and 403 feet long, will house the exhibit that is expected to attract 5,000 to 6,000 visitors. Equipment and supply booths will line the walls, and booths through the center of the building are planned for trade publications and machinery dealers. A machine weighing 13 tons will be exhibited, and the largest single firm booking for the show is nine spaces.

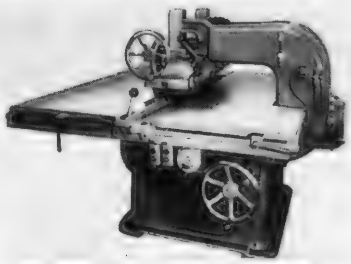
Exhibit hours will be 10:00 am to 5:30 pm, Tuesday, Wednesday, and Saturday, and 10:00 am to 10:00 pm on Thursday and Friday. Machinery booths, all except four, are 14 by 15 feet. Booths for manufacturers and distributors of equipment and supplies are 10 by 10 feet, and those for magazines and machinery dealers are six by eight feet.

To be held in conjunction with the show is the spring meeting of the American Woodworking Machinery Mfgs. Assoc., May 12, at the Sedgefield Inn near Greensboro, N. C. The Carolinas-Chesapeake Section of FPRS is also expected to meet during the show and attend the exhibits.

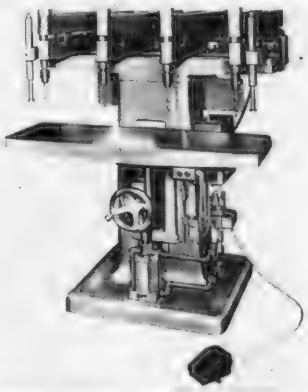
Exhibits and Exhibitors

A few of the 105 exhibitors and the machinery they will display are described below.

Ekstrom, Carlson & Co., Rockford, Ill., will show a Model E Rip Saw with yielding-type stock gage, large hand wheels for saws and pressure roll adjustment, hand wheel for infinite speeds of 56 to 225 fpm, and a 10–15 or 20 hp motor. Another machine to be shown by Ekstrom, Carlson is the No. 448 multiple spindle borer with four spindles, spindle rpm of 3600, minimum center distance between spindles of 2½ inches, and spindle chuck capacity of 1/16 inch to ½ inch.

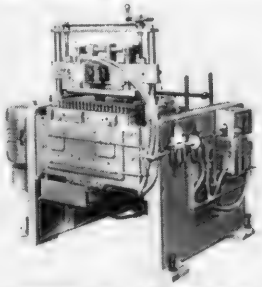


Ekstrom Carlson Model E Rip Saw



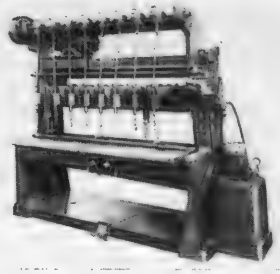
Ekstrom Carlson No. 448 Multiple Spindle Borer

New machines that will be displayed by Greenlee Bros. & Co., Rockford, Ill., are: No. 620 Dovetailer, which has twenty spindles, operates at 9,000 rpm, and has positive oil mist lubrication and adjustable pneumatic holddown; No. 436 Cut-Off Saw and table, which has variable air feed with hydraulic check control, aluminum head and cast iron base; No. 308 Hydraulic Feed Gang Borer, which has stationary table height, four-way foot control pedal, hydraulic spindle drive, and spiral gear top section spindle drive; and No. 310 Dowel Borer, which has a pneumatically powered feed stroke, power feed, power clamping, and spindles that adjust horizontally and vertically.

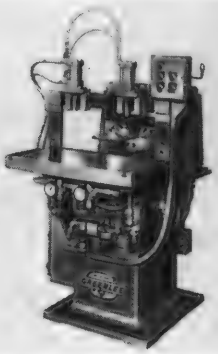


Greenlee No. 620 Dovetailer

Greenlee No. 436 Cut Off Saw

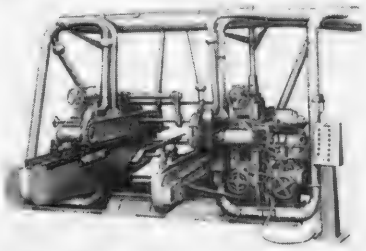


Greenlee No. 308 Hydraulic Feed Vertical Gang Borer

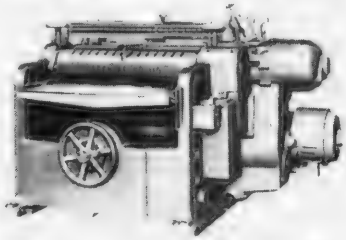


Greenlee No. 310 Two Spindle Horizontal Dowel Borer

Two older machines that Greenlee will exhibit are the No. 545 Double-End Tenoner that works to close tolerances; and the No. 110 Six-Roll Planer, a high production machine for single surface assignments, with rigid construction and head mounted in large, precision ball-bearings.



Greenlee No. 545 Double End Tenoner



Greenlee No. 110 Six-Roll Single Planer

Lemmon & Snoap, Grand Rapids, Mich., will demonstrate the operation of their flying cutter or Gulletless Saw, which is said to leave no saw flash, and does not grab the material.

(continued on page 38-A)

Marketing Theme of May 5–6 Pacific Northwest Meeting

The "Marketing of Forest Products" will be the theme of the May 5–6, Pacific Northwest Section meeting that will be held at the New Washington Hotel, Seattle, Wash., Section officials reported recently.

The two technical sessions will have sub-themes of: marketing of well-known wood products; and how to estimate the probable success of a new product. A field trip is also planned for the meeting.

Durability of Wood, Research for Utilization Discussed at Rocky Mountain Meeting

A technical program and election of officers were featured at the Rocky Mountain Section meeting, February 22, at Colorado State University, Fort Collins, according to V. L. Garrison, secretary pro-tem at the meeting.

"Natural Durability of Wood" was the subject of a paper presented by Phillip Opsal, of Colorado State University. He discussed the panographic method of separating and identifying the extractives of wood. It is believed, Mr. Opsal said, that these extractives are in some manner correlated with the natural durability of wood.

The role of research in wood utilization of the future was discussed by Ira Hatfield, Wood Treating Chemicals Co., St. Louis, Mo. Mr. Hatfield stressed the need for basic and applied research. The industries competing with the wood industries, Mr. Hatfield said, spend up to 20 times more per unit of product value for research than do the wood-using industries.

In business action, the Section elected officers for 1958. They are: W. R. Fritze, Koppers Co., Denver, Colo., chairman; W. Weiland, Broderick Co., Denver, Colo., vice-chairman; L. A. Mueller, Rocky Mountain Forest & Range Exp. Sta., Fort Collins, Colo., secretary-treasurer; and J. S. Weidman Lumber Co., Durango, Colo., trustee.

In other action, the Section voted to consider displaying wood materials at the National Meeting of Architects to be held in Denver this coming fall. Harry Troxell, chairman of the Research and Development Committee, was instructed to investigate the possibilities of a display.

Pacific Southwest Officers Elected at March Meeting

New officers were elected at the Pacific Southwest Section Meeting on March 5, in Los Angeles, W. E. Ripley, Jr., new vice-chairman, announced recently.

Officers elected were: A. J. Long, Monsanto Chemical Co., chairman; W. E. Ripley, vice-chairman; Olaf Anderson, Weber Showcase & Fixture Co., secretary-treasurer. J. H. Miller, Reichhold Chemicals, Inc., was elected to a two-year term as a Section board member.

Pallets to be Discussed at F–G–A Meeting, May 15–16

Pallet manufacture will be discussed at the Florida–Georgia–Alabama Section Meeting, May 15–16, at the Dempsey Hotel, Macon, Ga., Section officers report. A panel discussion on pallet manufacture will be held on the 15th, and the 16th will be devoted to visits to modern and efficient sawmills within a 40-mile radius of Macon.

Transportation reservations for the trips should be made by writing to Ralph Peter, U. S. Forest Service, Forestry Bldg., University of Georgia, Athens, Ga. Hotel reservations can be made direct.

Thirteen Titles Received for Wood Award Competition

Thirteen tentative titles, representing nine colleges and universities, have been received for the 1958 Wood Award Competition, according to the FPRS Executive Office. Represented are: Yale U; U. of Mich.; Iowa State College; Mich. State U.; U. of Minn.; State U. of N. Y. College of Forestry; Penn. State U; Alabama Polytechnic Inst., and Ore. State College.

FPRS Directory Announced

An alphabetical directory of FPRS members will soon be released, F. J. Rovsek, executive secretary of the Society, reports. The last directory issued was in February 1957 and was geographic in accordance with Society policy to publish geographic and alphabetical directories in alternate years. Members who desire a copy of the directory may place their request with the national office.

EMPLOYMENT SERVICE

The FPRS Employment Service is operated without charge as a service to members. Companies or institutions with positions to be filled or individuals seeking employment may participate in this program by inserting a free ad in two consecutive issues of the FOREST PRODUCTS JOURNAL. Inquiries concerning employment listings or ads to be placed in the JOURNAL should be addressed to FPRS Employment Service, P. O. Box 2010, University Station, Madison 5, Wis. Correspondence is kept confidential.

Positions Offered

E–308—Research chemist or chemical engineer wanted to head small, West Coast research group. Part of a national, multi-unit research and development organization. Mill or laboratory experience in paper, pulp, or other wood fiber utilization field desirable. (Apr.)

E–311—Position as assistant superintendent for flooring firm available. Engineering training or degree, and experience in veneer and plywood operations desirable. Knowledge of moisture controls, glues, lamination processes, and finishing desired. Will be responsible for improvements in quality, material handling, and line production. Salary commensurate with background and ability. Send resume outlining qualifications and personal history. (May)

Employment Wanted

No. 459—Position desired in production, sales, management, or research. Will have B. S. in Wood Utilization from Penn State in June. Sound preparation in basic engineering. Research experience in marketing of forest products. Will locate anywhere. (Apr.)

No. 461—Training and educated in forest management, and administration, research in forest utilization, management and economics. Can program research problems for and operate computational machines. Experienced as chemist. (Apr.)

No. 462—Sales position desired in wood products industries. Holds a BS in Business Administration, and is experienced as an industrial engineer in the plywood field. (May)

No. 464—Position in hardwood manufacturing or wholesale distribution work desired. Experienced in hardwood sales, manufacturing techniques, kiln operation and grading. Holds B.S. in Wood Technology. (Apr.)

No. 466—Position desired in product development or production in wood products. Has four years of college training in general forestry, and several months experience in office and field work in government and private agencies associated with forest products. (May)

No. 467—Executive engineer desires position in development, production, or management. Has 14 years of experience in pulp, paper, and wood products industries, including 7 years in design, construction, and operation of particle-board plants. Now associated with consulting firm but desires more direct participation in industry. (May)

Kill next summer's weeds now!

SOIL STERILANTS APPLIED IN WINTER AND SPRING KEEP GROUND BARE ALL YEAR

WEED KILLERS RECOMMENDED FOR WINTER AND SPRING APPLICATION

CONCENTRATED BORASCU*—Destructive to all types of vegetation. Can be applied dry, cast by hand or with a fertilizer or seed spreader. Concentrated form saves transportation, handling and storage costs.

BARON*—Dow Chemical Company's new nonselective herbicide that remains in the soil for extended periods of time, giving control of germinating seedlings following initial treatment. Mixes easily with water.

TELVAR* W—Industrial-use weed and grass killer produced by Du Pont. Wettable powder applied by sprayer, economical for large and small areas.

TELVAR DW—Similar to Telvar W but remains in soil longer under adverse conditions. Recommended for use in light, sandy soils and where rainfall is exceptionally heavy.

**BORASCU—Reg. trademark of United States Borax & Chemical Co., Pacific Coast Borax Co. Division. BARON—Reg. trademark of The Dow Chemical Co. TELVAR—Reg. trademark of E. I. du Pont de Nemours & Co.*

Now is the time of year to rid yards, roadbeds, and ditches of next summer's fire-hazardous weeds and grasses. Just apply an economical soil sterilant to eliminate all vegetation for a year or more. No need for costly periodic chopping or cutting, because the weeds are killed at their roots by the poison-laden rainwater. Mail coupon for more information on these effective weed, brush, and grass killers distributed by Chapman Chemical Company.

GET THE FACTS ON CHEMICAL WEED KILLERS

CHAPMAN

CHAPMAN CHEMICAL COMPANY
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Minneapolis • San Francisco • Portland, Ore. • Charlotte, N. C.

Distributor of a complete line of weed, brush and grass killers produced by leading manufacturers.

CHAPMAN CHEMICAL COMPANY
P. O. Box 138, Memphis 1, Tenn.

Please send complete information on chemical weed killers checked:

☐ Concentrated Borascu ☐ Baron
☐ Telvar W ☐ Telvar DW

*Name*_____

*Address*_____

New Type Spool Sanding Ups Production 400%

Another new production booster—this new type coated abrasive spool cover for sanding molded edges of table and dresser tops. Where before, two dining-room table tops were sanded per ordinary 16-wing disc—40 are sanded with this new 32-wing spool cover.

A Behr-Manning methods engineer can save you time and material . . . just phone your nearest office for a date.

There are 17 "Abrasive Tech" Methods Rooms well-equipped with the latest equipment of all manufacturers (Behr-Manning does not make or sell machines) located at: Atlanta, Boston, Buffalo, Chicago, Cincinnati, Cleveland, Detroit, Grand Rapids, High Point, Indianapolis, Los Angeles, Teterboro, Camden, San Francisco, Seattle, St. Louis, and Brantford, Canada. Main office and plant: Troy, N. Y. For Export: Norton Behr-Manning Overseas Inc., Troy, N. Y., U.S.A.

BEHR-MANNING CO.

TROY, N. Y.

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BEHR-MANNING PRODUCTS: Coated Abrasives • Sharpening Stones • Pressure-Sensitive Tapes • NORTON PRODUCTS: Abrasives • Grinding Wheels • Grinding Machines • Refractories

FPRS Forest Products Journal

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Technological Advances in Veneer and Plywood Materials, Machines, and Methods[1]

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Both merchandising changes and technological changes are essential to improve the situation of the veneer and plywood industry. An up-to-date, descriptive summary of the most important advances in both of these phases, observed in plants in the United States and abroad, is presented.

BUSINESS IN GENERAL, and plywood in particular, is suffering a definite recession. Many factors are probably to blame. We are looking for ways to solve our problems by both merchandising and technological changes. So when searching frantically for solutions to our difficulties, we may be guilty of becoming too excited over something new or, contrariwise, not receptive enough to radically necessary changes. Somewhere in between these two extremes of behavior should lie the solid basis for economic growth and efficient progress.

Nothing so drastic as a Sputnik is likely to happen in the veneer and plywood industry, but we should apply a great deal of considered introspect in regard to our individual problems. Needs and conditions should be studied well in advance before we make great changes, and when we have analyzed our problem, we should avail ourselves of all the new ideas, or as many as possible.

Progress Must Start With Merchandising

Real study should begin at the consumer level. All types of industries have come to realize the necessity of drastic changes necessary in the proper merchandising of their products. In the veneer and plywood field, the standards of grading of wood products, such as standard lumber grading rules, which designate quality, are almost impossible to present, make attractive, or establish in the minds of the consuming public. Who buys his cloth or materials from a decorator, or designs by any set of standards? The categoric answer is "no one." It is individuality and personal choice that govern.

This selling is beginning to evidence itself in plywood. Many manufacturers, the biggest and smartest merchandisers, are establishing unique products that are sold solely on the merits of their appearance, attraction, and value.

Pre-finishing of wood products is the first big avenue leading toward this goal of placing plywood products on the same basis of consumer acceptance as drapery materials or paper coverings. A definite lessening can be seen in resistance to prefinish by distributors, and also at the retail level.

And with pre-finishing comes, of necessity, mechanization. Hardwood plywood manufacture, with its many species, constructions, and sizes, has offered many understandable problems in mechanization. But pre-finishing—that is, coating, drying, conveying, and so forth,—of necessity dictates mechanical handling, conveying, or both. Since the advent of factory finishing, many producers have been surprised to discover how much more conveyorizing, mechanical handling, turning, and storing can be done. Plywood producers don't need to go off in all directions in excited confusion, nor should they stay in a shell of conservative isolation. The solution to most economic problems lies in careful analysis of troubles, and open-minded consideration of the possible solutions. This paper will exclude, of course, the problems involving our

The St. Paul & Tacoma Lumber Co. uses a Laucks continuous moisture detector in the surveillance of the plywood they produce.

[1] Presented before the Hardwood Plywood Institute, Feb. 14, 1958, in Washington, D. C.

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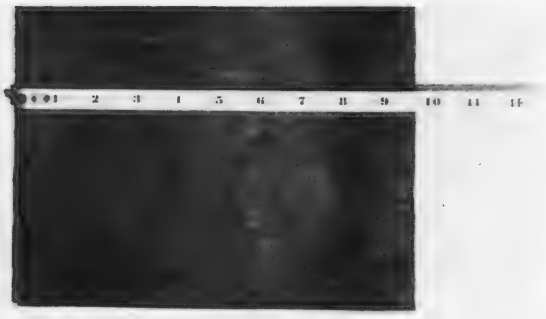


The "before" condition of 3/16 hardwood veneer about to undergo stretching on the Higgins Lumber Stretcher.

The "after" condition of the same piece of hardwood veneer. There is no measurable difference in thickness or grain pattern.

State Department. It will present a few ideas that have resulted from research, development, and new approaches to the problems of plywood.

Thinking Should Begin With Wood Itself

We should recognize the need for enlarging our varieties of wood, especially as applied to veneer slicing. Generally, we use only walnut, oak, birch, and the mahoganies; yet we have a number of native woods that should be considered as sliced-veneer material. This is especially true in view of the consumer demand for new and different kinds and effects in wood. We might even suggest the use of logs of species and quality that previously have been rejected. Even aspen, a fast-growing type, might be used. It has a pleasing color, appearance, and is readily workable, and some logs often have attractive figure. The Early American tradition in furniture and wall paneling could easily be fulfilled by the use of southern yellow pine for slicing. Overcup oak, as indicated in laboratory tests, could make very attractive panels. When quartered and sliced, it is not subject to the problems of honeycombing, warp, and checking, which are usually found in overcup lumber.

It has also been shown that very good veneer can be sliced from logs of lower quality than would produce good rotary material. In hardwood paneling, some of the natural defects in wood that would be eliminated under standard grading rules usually find warm acceptance by the consumer, even though the distributor might not like them. It is also very evident that material from logs of this type could best be sliced on machines half as long as are normally used. Small slicers work faster and more accurately, and better quality slicing is produced on the new, modern, small slicers. Much thinner sheets may soon be acceptable in the trade than are now standard.

On the other hand, 1/10 or 1/8 oak, either sliced or rotary cut, might be an excellent answer to the competition in wood flooring presented by linoleum, asphalt tile, and so forth. In fact, Frank Higgins of Higgins Industries, New Orleans, has designed and patented a machine for stretching veneer in its green form to such an extent that, after it is dried, it is a little larger than it was prior to the stretching. The Company intends to exploit this product as a veneer hardwood floor.

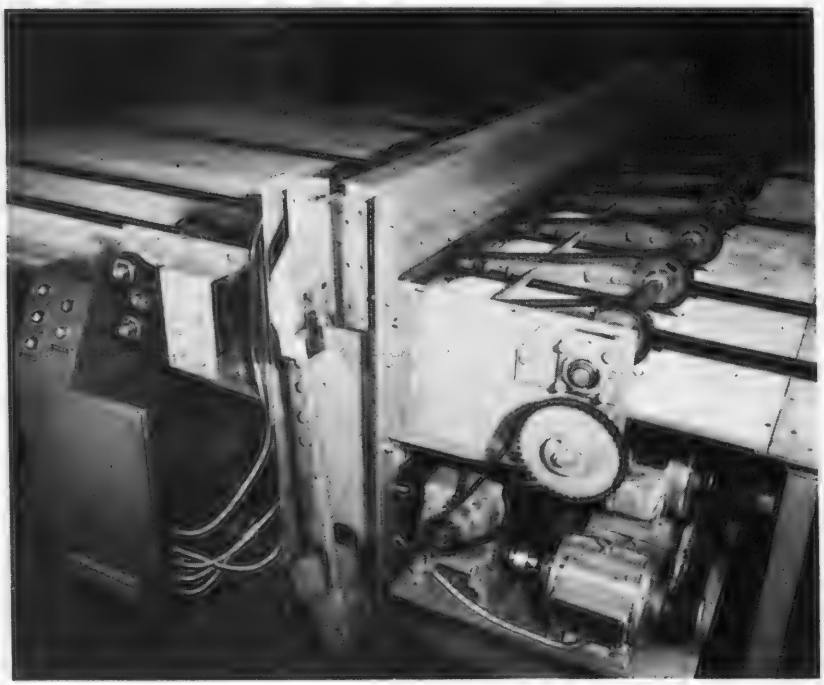
Veneer Cutting and Handling

Another new and interesting piece of machinery in veneer manufacture is the Cardwell Auto Clip. This machine is activated by a chemical that is placed on the veneer at the defect. The machine senses the presence of the chemical and cuts out only the defect. It automatically aligns the veneer with the knife after the grader has placed the chemical on the veneer, which is conveyed by belts through the automatic knife. Greater yields and accuracy result.

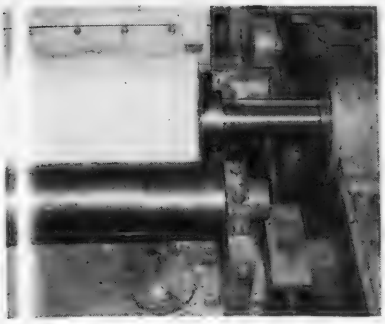
At F. Eggers Plywood it has been found that veneer logs steam heated under slight pressure have overcome many of the problems of water and atmospheric pressure steam in the past, and that a great deal of savings and higher yields have resulted through this means.

One of the greatest costs of manufacturing veneer prior to making plywood is the waste within the veneer itself. The veneer clipper just mentioned, continuous cross-feed veneer splicers, and automatic jointers with glue applicators, such as made by Fischer in Switzerland and Ruckle in Germany, are available now in much more highly developed form than existed a few years ago.

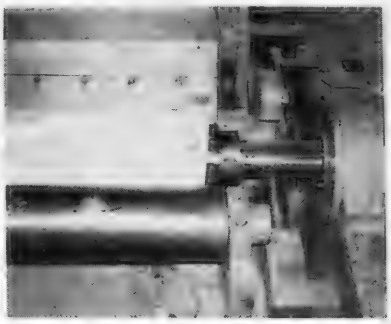
For those who peel large logs, Jackson Industries of Birmingham, Alabama, has developed a lathe with inner and outer chucks. Both engage



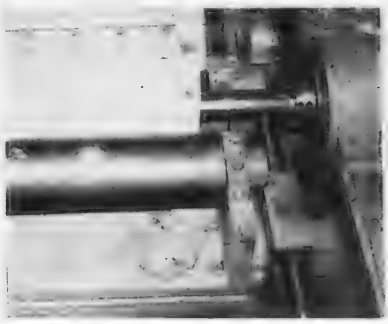
The Cardwell Auto Clip, activated by a chemical placed on defects in the veneer, automatically removes only the defect, increases yield and accuracy.



O er and inner chucks holding the block on a Jackson Retractable–Chuck Lathe.



The outer chuck is being retracted as the diameter of the block is reduced.



Here the outer chuck is fully retracted and out of the way of the knife.

tl log, but at a pre-determined diameter of core, the large chuck and spindle withdraw and the core is turned down on the small-diameter chucks to about a 3½-inch diameter.

Owens–Illinois Plywood reports that, by the use of gripping apparatus similar to that used in the pulp industry for the handling of veneer flitches and logs, they have reduced the defects caused by grappling tongs by as much as 12 per cent in the finished product, and the cost of handling by as much as 50 per cent. Yield of finished product, veneer, is increased through elimination of holes ordinarily caused by hooks.

A method of feeding veneer direct from the lathe to the dryer as used by the Allan Quimby Co. is a tremendous step in the elimination of handling costs of green veneer. Quimby's equipment may not be available commercially, but one is being made by "Tromag" in south Germany.

Electronic continuous moisture detection and marking devices are available through Laucks–Sentry and Mann–Russell, both on the West Coast.

Chester B. Stem at New Albany has built a veneer-handling rig that reaches inside a box car and places veneer crates anywhere the operator chooses, with one man handling the entire operation. Stem has also found very advantageous the use of closed circuit television at 5 key places in their plant so that their office can know exactly what is being cut, how it is being cut, and the quality of material produced.

The organization also employs a spot-welding steel strapping device which eliminates a crating operator, since the man who measures does his own crating. The quantity of the veneer has been measured previously by a system of photoelectric cells or electric eyes.

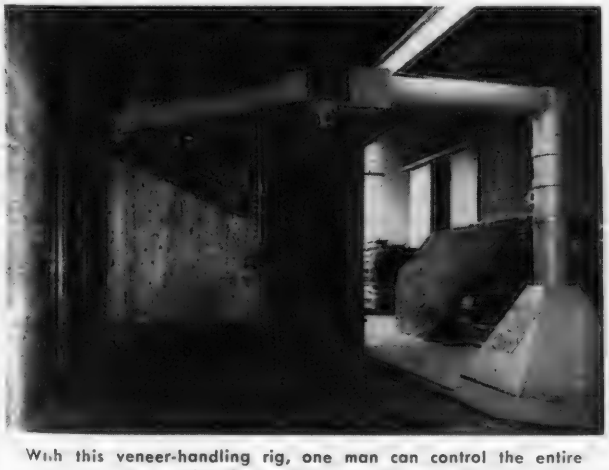
Nickey Brothers has designed a most inexpensive reeling and unreeling system that has cut the cost in rotary veneer making by as much as 40 per cent. This is somewhat patterned after a type made in Japan, but works better. It is now available through Wilco Machine Works in Memphis.

It has long been known that we need much tighter control of temperatures, pressures, and processes in hot-plate pressing. The advent of new electronic circuiting coupled with advances in temperature monitoring will likely result in economical control of individual platen temperatures.

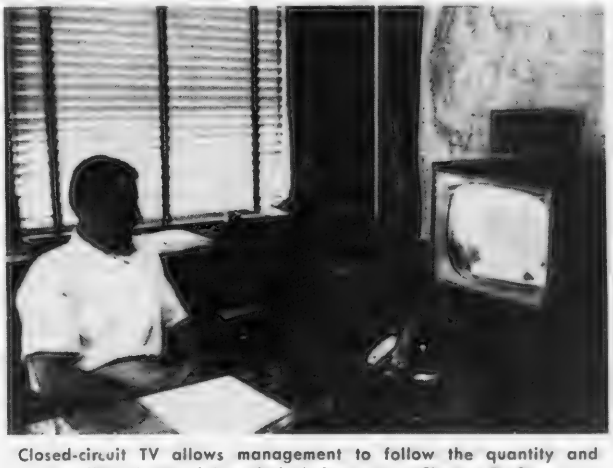
A spectacular departure from the conventional method of jointing veneers has been developed by the Globe Machine Co. of Tacoma, Wash. This machine has a rotating clamp which, through a complete circle of the rotating head, clamps the veneers, moves a quarter turn, releases, shakes, reclamps, turns another quarter, joints and applies glue, turns another quarter, releases, shakes, and turns another quarter to the cutterhead and glue applicator for the other edges of the veneer. After this, the veneer is automatically moved out of the clamps and fed in single sheets through a Mann–Russell cross-feed continuous splicer.

The Williams and White Company has now developed a simultaneously opening press for the plastics and

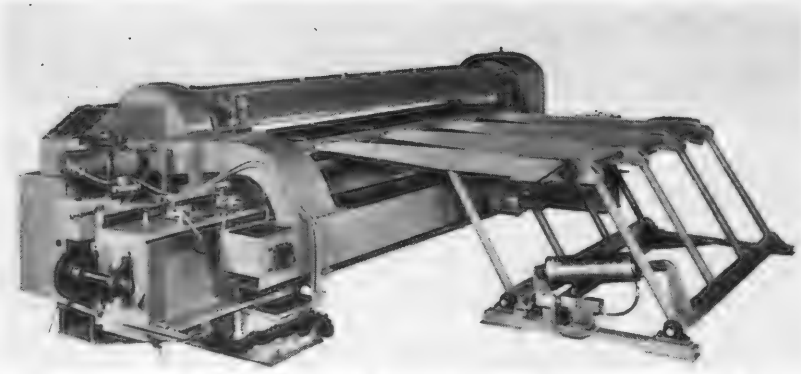
This spot-welding steel strapping device eliminates a crating operator at Stem.



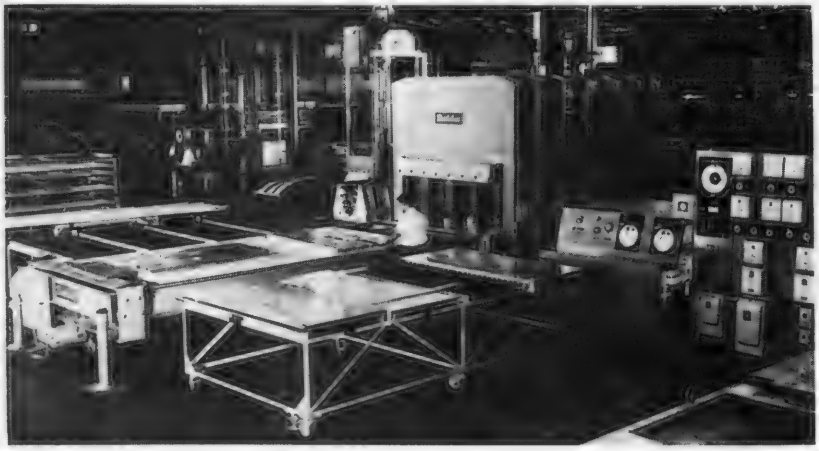
With this veneer-handling rig, one man can control the entire operation for easy, optimum loading.



Closed-circuit TV allows management to follow the quantity and quality of material as it is being cut at Chester B. Stem.



This new jointer, developed by Globe Manufacturing Co., is unconventional in that it operates on a rotating-clamp principle.

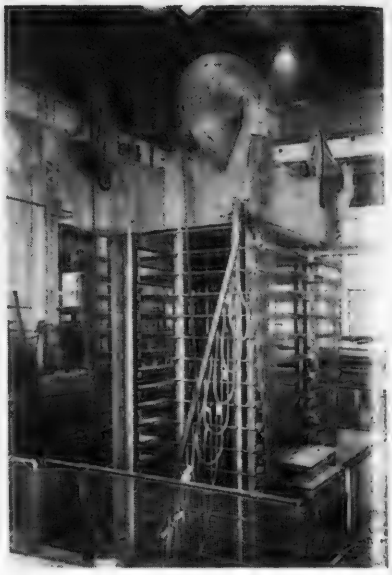


Both Berthelsen (above) and Fjellman–American produce quick-opening presses with allied loading and unloading.

high-pressure fields, and it seems that this principle may be available in plywood pressing to speed up the handling of the plywood assemblies and to reduce to a minimum the hazard of pre-cure.

Berthelsen Engineering Co. and Fjellman–American Co., both of Joliet, Ill., have disclosed quick-opening presses with allied loading and unloading that also include side-pressing devices for edge handling.

A new thought in plywood pressing is advanced by the Berthelsen Co., in which they are designing presses that begin with normal pressing pressure at the beginning of the cycle, but by a new system of scientific controls, the pressure is gradually lessened during the pressing to reduce to a minimum the compressing of veneers. This means that thin veneers can be used to produce required thicknesses, and in some cases up to 15 per cent volumetric improvement, depending upon the thickness of the finished product.



A simultaneously opening press developed by Williams-White. This type of press might well be adapted to plywood.

A great deal of study and thought by manufacturers is going on in the surfacing and thicknessing of plywood.

An outstanding step in this direction is the advent of the wide-belt sanding technique (manufactured by Time Savers Sanders, Sherrill Machinery Co., Curtis Machine Division of Carborundum Co., and others), which speeds up the operation to such an extent that one plywood manufacturer reports that their sanding faults have decreased 75 per cent and man-hour production has tripled while complaints from customers have been greatly reduced. This success of these machines has been made possible only by the successful development of better abrasives, cloth, paper, fiber, and bonding resins. Carborundum, Behr–Manning, and Minneapolis Mining & Manufacturing are among those spending large sums in the research and development necessary to this progress.

Step-up of four Timesaver "Speedbelt" Sanders for rough and finish sanding of flush doors.

The MicroGrinder for close finishing on veneer. Models are available for sanding materials on either top or bottom.

Wide-belt sanders can be obtained in both top and bottom types, so that conveyorizing from one machine to the other is the logical way of handling the material.

Finishing Treatment

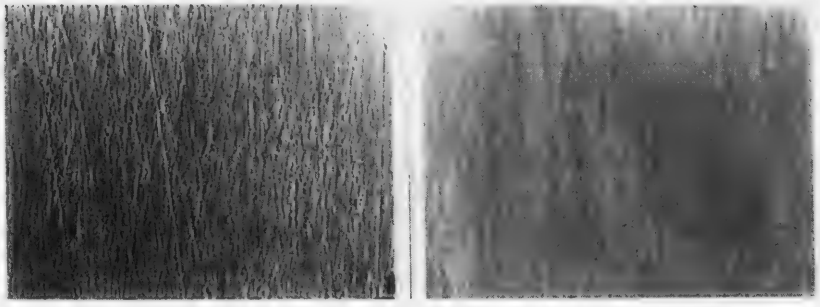
It was by the use of machines of this type that use a special non-abrasive belt that the General Plywood Corporation developed what they call the Super Microseal process of Surface treatment for plywood, or any other wood product. These wide polishing belts apply considerable pressure and heat for a brief moment, at which time it appears that the lignin in the surface of the wood flows and redistributes itself in the surface so as to produce a sealing effect. Nickey Brothers uses this process exclusively on their plywood, and has had unexpectedly good customer acceptance, in fact they now demand it. The Super Satin Surface products are the same thing as the Satin Surface except that a resin additive is worked into the surface of the wood, where it is dried and cured. It is a great step toward the upgrading of plywood and in promoting ease of further finishing, if required.

Much thought has been spent recently on the improvement of plywood through sanding of veneers prior to assembly. This includes both cores and faces. A sanding machine of extraordinary accuracy is the Curtin–Hebert Micro Grinder. It has been used for many years in other industries, but is now the tool for research by certain abrasives manufacturers.

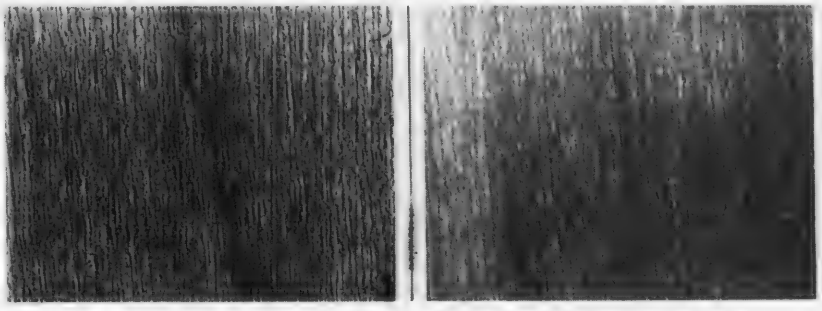
Another method of factory finishing is the PERM–A–FILM coating. This process was developed by the Sorg Paper Company, and is patented by them. The process consists of the application of a transparent vinyl film onto wood, which gives a highly resistant surface to most of the hazards normally expected of wood. Acids, alkalis, and all normal stains have no effect on the finish whatsoever, and are not transmitted to the wood.

It is unnecessary to expound upon prefinishing methods that involve fillers, sealers, synthetic coatings, and so forth, since many producers are already enjoying public acceptance of very high quality finishes of this nature. It should be added, however, that the Super Microseal Process used at Nickey Brothers employs, in addition to the normal Super Microseal process, certain plastic penetrants that make it also highly resistant to staining and abrasion that may normally be expected.

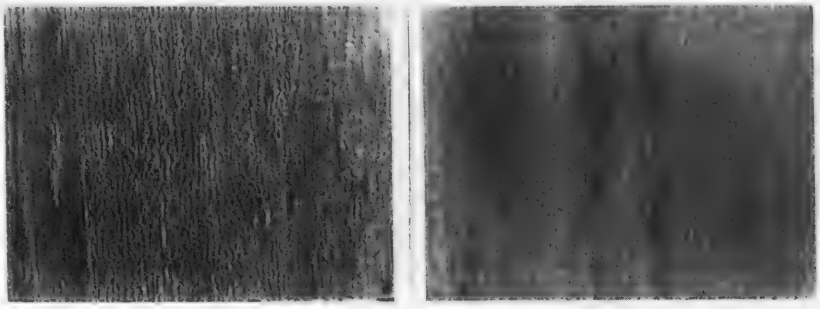
Another very beautiful finish that is in use in St. Margarethen, Switzerland, employs the use of fancy faces and conventional backs applied to hardboard panels. Light sanding of the faces is followed by an application of melamine, which is allowed to air dry. The panel is then placed between chrome-plated cauls for a 10-minute press cycle, which results in a tough, satin finish of high quality.



Left, conventionally sanded gum plywood; right, gum finished by the Super Microseal process.



Left, conventionally sanded birch plywood; right, birch finished by the Super Microseal process.



Left, conventionally sanded Douglas-fir plywood; right, fir finished by the Super Microseal process.

A similar treatment is applied to hollow-core doors at Schweningdorf and Gohfeld, Germany.

The plant of Bosse at Stadhagen, Germany, manufactures plywood school desk tops with the two upper plies previously impregnated with liquid resin and bonded with a dry urea film. The finished plywood is later given a surface of dry melamine film and re-inserted in the press for curing. This provides a tremendously resistant surface to wear, and keeps wood in an area that was rapidly being lost to other products.

Another German machine made by Ulrich Steinemann applies liquid finish by passing the wood through a solid veil of finishing material at very high speed. This makes it possible to apply the finish to curved or molded surfaces. Heat drying in the conventional manner will follow the application of this finish. Air-less spraying is the newest technique in spray methods —it results in no excess spraying and better control.

Conveyorizing and mechanization thru the drying stages naturally follow, and at this point attention should be centered on the ceramic-cone electric heating units that are designed to take the place of incandescent lamps. The electric heating element is imbedded in the ceramic so that the entire heavy unit attains a red glow and carries its heat considerably longer after the current is turned off by a controlling thermostat. In this way, a much more even control of heat can be applied to the surface than is possible by the off-and-on method of incandescent lamps.

For those interested in door manufacturing, the F. G. Konstandt Co. of Hamburg, Germany, has developed

The recently finished prefinishing line for doors and hardwood plywood at the Roddis Marshfield plant.

and patented a method of flush-door making that makes use of spiral coils made from residue wood. The coils are easily and efficiently assembled, and give very firm and frequent support to the skins of the door. These doors are being manufactured very successfully in England and other parts of the world, and on a very economical basis. This appears to be the newest approach to light, strong core material.

Most manufacturers are familiar with the great developments that have taken place in gluing, but a new element has come into the additive field which is a clear chemical that makes glue have a stronger affinity for wood, or, for that matter, metals or glass. This is just beginning to be manufactured in a large way in Switzerland, and should be available in a short while in the United States. This additive is very startling in the way it lowers weight of glue spread while maintaining even better bond quality. Over-all glue line costs are reduced from 20 to 30 per cent.

One of the most interesting solutions to the problems of handling plywood and storing plywood after it is manufactured exists in the warehouse of the Singapore Plywood Company, which employs an overhead traveling crane with full revolving fork-lift attachment. The crane affords a completely flexible operation, and gives great selectivity to the handling of plywood packages. This crane is manufactured in England.

Veneer and plywood manufacturers should not overlook the possible correlation of veneer waste and cores with particle board manufacture. When the economics indicate it, consideration should be given to utilization of waste in particle board, later to be laminated with veneers, or at least to finding a particle board mill that will use the waste.

Each manufacturer should be aware of the availability of research organizations, other than his own, if he is so fortunate as to have a research laboratory. The Forest Products Laboratory at Madison can be of great help in many ways if its services are sought. A list of private and other semi-public organizations doing active work in research in veneer and plywood was published in the February, 1958 *Annual Review* issue of the FOREST PRODUCTS JOURNAL.

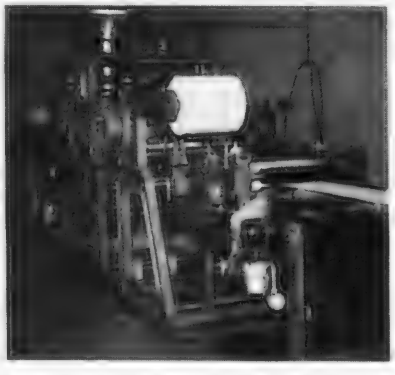
Quality Control is Indispensable

But it doesn't matter how hard one works or how conscious he is of quality and profits, some form of quality control should be diligently pushed through the entire manufacturing process. The latest method we know of—quality control by the statistical method—is so versatile and flexible as to have an application in any plant. Its advantages and ramifications are so many as to make it impossible to describe adequately as part of another subject. But our experience has been such as to warrant this technique to all manufacturers, and no paper on modern processes would be complete without reference to this manufacturing tool.

Conclusion: Learn From Others, Also

In conclusion, one of the best methods of evaluating one's own operation and of getting new ideas quickly is to travel and visit other plants. Certainly this travel should not take the place of study within one's own plants for his own particular operations. It does mean, however, that a great deal can be learned where other manufacturers allow visitors—and most of them do.

In addition to the pleasure of travel and seeing things it is highly stimulating to the imagination and to manufacturing progress.



Equipment used for applying Sorg Paper Co.'s Perm-A-Film coating onto wood. A transparent vinyl film provides a highly resistant surface.

Development of a Highly Accelerated Test for Water-Resistant Hardwood Plywood[1]

C. ARTHUR HART

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This test employs extent of delamination at the end of a fixed period of rapid wet-dry cycles at an increased temperature as the index of plywood quality. A new test specimen has been developed that makes possible a test which has the advantages of a great reduction in time required, economical adaptation to fully automatic cycling controls, minimum man-hours, and still retains a sensitivity comparable to the present standard test.

THE OBJECTIVE OF THE RESEARCH presented in this paper is the development of a more rapid test method for determining the durability of Type II (water-resistant) hardwood plywood. This project was undertaken as a result of the need for such a test as expressed by the plywood industry. The present standard test, as specified in the current Hardwood Plywood Commercial Standard, requires up to 15 days for acceptance or rejection of a plywood shipment or lot. Each soak-dry cycle requires 24 hours, and up to 15 cycles are required for testing. Such an excessive length of time before test results are known very seriously impairs the utility of the test, and a substantial reduction of this time is of primary importance in the development of a new test method.

Considerations in Development of Test Methods

Under actual service conditions, temperature, hydrolysis, mechanical stress, and attack by microorganisms may all contribute to the deterioration of a glue bond. A short-term durability test must attempt to accelerate as many of these factors as possible if it is to predict performances under long-term exposure conditions. Although no single test may be expected to provide a complete evaluation of glue-bond quality, the requirements of industry necessitate the use of a simple testing procedure as a reasonably accurate index of durability.

In addition to the above factors, there are a number of practical considerations in the development of a suitable test for industrial use. Testing variables must be subject to sufficient control to insure that the test may be accurately reproduced. Sensitivity, time, manhours, equipment, the restrictions of an 8-hour day, and the amount of information provided are all important considerations. The sensitivity must obviously be sufficient to satisfactorily indicate the extent of durability. The less time expended before test results are available, the more useful the test will be. This is particularly true in industrial applications of both acceptance sampling and quality control.

It is highly desirable that the suitability of a given plywood lot be determined before the shipment leaves the plant. This cannot be accomplished with the present standard test because of the length of time required for the test, with the result that an unsatisfactory lot may not be discovered until after it has reached its destination. In addition, the factors that caused the plywood glue bond to be unsatisfactory may have continued to exist, unknown to the plant personnel. For the purpose of providing a basis for immediate corrective action in the control of the variables of production, a rapid determination of product quality is essential. Such a determination is not possible with the present standard test.

The amount of information provided by a test strongly affects its utility. For acceptance sampling, a simple "accept" or "reject" may prove completely satisfactory. For use in the control of production variables, however, a test is needed that will also provide a measure of the general level of quality that is being maintained in current production. From the standpoint of profitable operations, the expense of maintaining a quality level far in excess of that which is satisfactory can be as serious an economic considerable as that of an occasional production lot which is unacceptable.

Basic Types of Tests

In the development of this project, three basic types of tests were considered:

1. The time of exposure expended before a specified extent of delamination, or separation of the glue line, occurs;

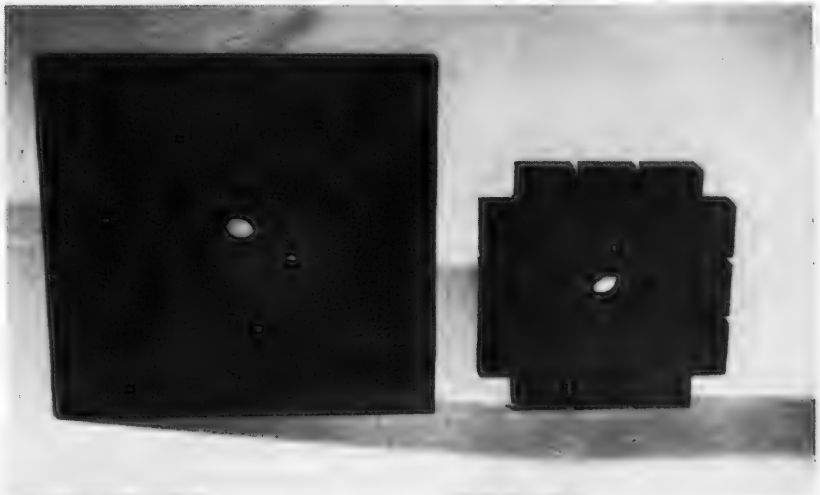

Fig. 1.—The standard 6-inch-square specimen, and the experimental 4-inch-square specimen with arrows indicating grain direction.

[1] Presented at Session III, Veneer and Plywood, of the Eleventh National Meeting of the FPRS, held June 23-28, 1957, in Buffalo, New York. The paper is a portion of a thesis submitted at N. C. State College for a PhD degree.

The Author: C. A. Hart holds a BS in forestry from Virginia Polytechnic Institute, and an MS in wood technology and a PhD from North Carolina State College. He has been employed by the N. C. Wood Products Laboratory since 1954, and directs research in Timber Physics and Mechanics.

2. The mechanical strength retained by the glue line after a fixed interval of exposure;
3. The extent of delamination after a fixed interval of exposure.

This list is by no means intended to represent a complete inclusion of all possible types of testing, but rather is a useful index of the basic types widely employed in the durability testing of plywood. The term exposure is intended to refer to the use of temperature and moisture for the purpose of accelerating the deterioration of the adhesive. This exposure may vary from subjecting the plywood to the rigors of climate, as in the outdoor test fence, to the use of specified soaking and drying periods at controlled temperatures. For the purpose of developing a rapid durability test method for use by the industry and by research workers, it was felt that the determination of the effect of some type of controlled exposure to temperature, moisture, and mechanical stress offered the best means of evaluating the durability of plywood. Thus the three basic types of tests as listed here may be considered as representing three methods of determining the effect of the exposure conditions upon the plywood. They may well be used in combination, and there are, of course, innumerable choices in regard to exposure conditions of temperature and humidity.

Analyses of Basic Types

The present standard test for Type II hardwood plywood measures the time of exposure expended before a specified extent of delamination occurs. Time of exposure is measured by the number of exposure cycles completed before the occurrence of two inches of continuous delamination along any edge of any glue line of a six-inch-square test specimen. A cycle of exposure consists of four hours of water soaking followed by 20 hours of air drying, both at room temperature, and a maximum of 15 cycles may be required.

Examination of the specimens at the completion of each cycle is necessary, which presents very serious difficulties in any attempt to increase the rapidity with which this type of test may be accomplished. Extensive reduction of the length of each cycle results in almost constant supervision being required by personnel conducting the examination of the specimens. The length of time required for each examination of the specimens, the constant repetition of the examinations, and the economic considerations imposed by the 8-hour work day appear to present almost insurmountable difficulties insofar as visual examination of the specimens is concerned.

To circumvent the above difficulties involved in visual examination of the specimens, automatic mechanical means of determining the time at which failure occurs may be proposed. A number of possibilities were considered, but none was found that did not require the use of rather expensive testing apparatus. This approach does remain as a distinct possibility, however.

The second basic type of test listed involves a measurement of the mechanical strength exhibited by the glue line after the completion of a period of exposure. Automatice cycling equipment could be employed, if necessary, so a critical analysis of this type of test centers on the method of obtaining a measurement of the mechanical strength retained and also on the meaning of this measurement once it is obtained. The principal objections presented here are the difficulties involved in examining all glue lines of a plywood construction, and the meaning of the results obtained in regard to different constructions. Techniques employed to obtain a strength figure may vary from a pounds-per-square-inch figure from the standard plywood shear test to a judgment analysis from the use of a knife or tool to separate the plies forcibly.

Regardless of the method employed, every plywood construction has its own particular requirement in regard to the strength of bond necessary for satisfactory service performance. From the standpoint of rapidity of testing, however, this type of test seems much more promising than the first type in which the measurement of time is involved.

The third type of test listed differs from the second in that extent of delamination rather than a measure of applied mechanical stress is incorporated for determining the degree to which the glue bond has been weakened by the exposure treatment. Thus it also has the same advantage as the mechanical type in that automatic cycling equipment may be used. In addition, it is a simple approach that requires only the visual examination of the specimen edges for delamination, and does not require mechanical stressing apparatus. With cyclic exposure to wetting and drying with the resultant swelling and shrinking, each specimen stresses the glue lines as a natural result from the construction features involved, such as species, density, and thickness of veneers. Performance is dictated by the weakest glue line, as it properly should be. An apparent disadvantage to this type of test is that a complete measurement of all areas of delamination, on every glue line of every edge, would be a time consuming task. If a simple and rapid technique could be devised for this purpose, however, it was felt that this type of test offered unique advantages for the development of a very rapid durability test.

Design of Specimen

A number of exploratory investigations resulted in the adoption of the experimental test specimen pictured in Fig. 1. A 4-inch-square piece is prepared with the grain parallel to the diagonal of the square. Saw cuts are made to a depth of 9/16 inch on one inch centers, starting ½ inch from a corner, thus giving three separated edges on each edge of the specimen. Although this is a fairly substantial amount of machining, it is not believed to be excessive.

Only two settings of the guide fence and one depth of cut setting are required of the table saw. The first setting of the guide fence permits all the corner cuts to be made with the resultant removal of each corner. A second setting of the guide fence permits the remaining cut to be made. A number of specimens may easily be machined simultaneously.

Two considerations resulted in the adoption of the diagonal grain orientation. The first was the fact that, with certain types of construction, two edges of a specimen without this diagonal grain orientation will delaminate more rapidly than the other two. If all plies exert equal force in swelling, the face and back plies will produce more rapid delamination on the two edges parallel to their grain. This fact was shown by the author in a previous project[2] and substantiated by the exploratory experiments preceding the present project. For quality-control applications and for mathematical or statistical analysis of test data in research investigations, it is desirable that all edges have an equal probability of failure. This consideration also led to the disposal of the corners so that each of the smaller edges would be more or less independent of the delamination of adjacent edges.

The second consideration leading to the adoption of the diagonal orientation was the rate of moisture movement in soaking and drying. With this specimen, end grain of every ply is exposed at a 45° angle on each edge. Since extremely rapid soak-dry cycles were contemplated, this was an important consideration.

To determine the extent of delamination of a given specimen after ex-

[2] Hart, C. A. 1956. Effect of temperature variation on the results of the cyclic exposure test for glue bond durability. Forest Prod. J. VI (7): 247-51.

posure, each of the 12 edges are examined for glue-line separation. A given edge is considered to have failed if any one of its glue lines exhibits delamination along the entire 7/8 inch edge length (since a 1/8-inch kerf is taken on one-inch centers, each small edge is 7/8 inch in length). Thus each edge either passes or fails, and the number of delaminated edges may vary from zero to 12 for a given specimen.

This determination may be made with relative ease and rapidity. No attempt is made to measure depth of delamination, so only a rapid visual examination is required. Also, with the standard specimen currently in use, difficulties occasionally arise when lathe checks tend to open up at the glue-line edge. This problem does not exist with the diagonal grain orientation.

For ease of handling, both the standard and the experimental test specimens were racked on 3/8-inch aluminum tubes with the specimens being separated by 3/16-inch-thick rubber washers. (Fig. 2). This technique is readily adaptable to automatic cycling controls.

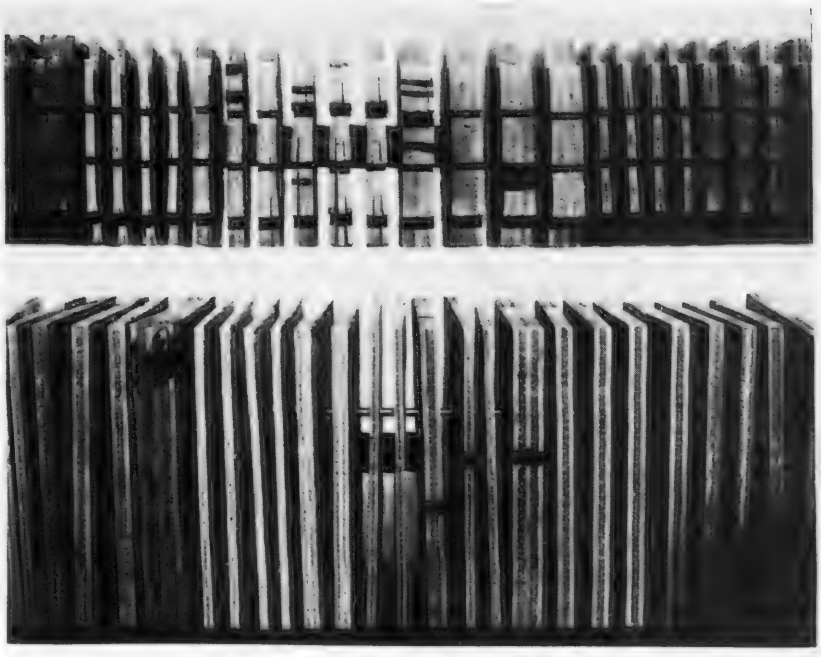

Fig. 2.—Method of mounting specimens on the racks.

General Testing Approach

The selection of a general approach for the experimental treatment was dictated by a consideration of both the technical and economic factors involved. This resulted in a treatment of soaking in water and drying in air at an elevated temperature, with both water and air temperature being maintained by the same controls. This approach requires only a forced-draft, temperature-controlled oven or heated chamber with a suitable container of water placed in it. The temperature would have to be sufficiently higher than the extremes of climatic conditions to insure that neither cooling equipment nor humidity control equipment would be required. Air velocity and temperature should be of sufficient magnitude to insure adequate drying of the specimens.

Both the water for soaking and the air for drying were subjected to the same temperature control to provide for ease of adaptation to fully automatic cycling equipment.

Design of Experiment

Following the development of a satisfactory experimental specimen and the adoption of a general testing approach, an experiment was designed to attempt the determination of a suitable cyclic exposure treatment to produce the desired extent of delamination for a plywood panel of a given durability. For lack of a better method, the panels were to be indexed for durability by the standard cyclic test, and the experimental test results were then to be compared to this index. The variables of panel construction were as follows:

- 6 glue mixes: UF 65–100 (Urea formaldehyde, 65 per cent solids, 100 per cent wheat flour extension based on resin solids), UF 65–150, UF 45–100 (dropped from final analysis), UF 45–150, Casein, and Soybean;
- 2 species: red gum *(Liquidambar styraciflua L.)*, and yellow-poplar *(Liriodendron tulipifera* L.);
- 2 veneer thicknesses: 1/16 inch and 1/8 inch rotary cut;
- 2 constructions: 3 ply and 5 ply (only plies of the same thickness were used for a given panel).

All combinations of the above variables gave 48 panels, replicated to give a total of 96 panels. Each panel was of sufficient size to finish slightly larger than 36 inches by 12 inches, with the face grain parallel to the smaller dimension. The four glues were obtained as typical commercial formulations from the manufactures, and two extensions were made with each of the U.F.'s as indicated.

All veneers were conditioned to a 9 per cent moisture content (based on oven dry weight) prior to gluing. The U.F. panels were hot pressed, while the casein and soybean were cold pressed. A spread of 40 pounds per 1000 square feet of single glue line was used with the U.F.'s, and 60 pounds with the casein and soybean. Many of the veneers displayed evidences of rough cutting and fuzziness of the surface.

Also, the entire permissible range of assembly time was used for the protein glues, casein and soybean.

One of the greatest difficulties in this type of experiment is to obtain panels of the proper durability level. In this instance, an average durability of 10 cycles by the standard test was sought, and the primary concern was that of obtaining too high a durability level for the purposes of the experiment. The experiment was designed for the purpose of seeking a suitable experimental treatment on a trial-and-error basis, with each successive trial dictating the treatment that would be investigated next. The objective was to find a 24-hour treatment that would produce approximately 50 per cent delamination of the experimental specimens taken from panels whose quality index as determined by the standard test was 10 cycles.

Results

As trial runs were attempted, it quickly became apparent that the difference between the responses of the U.F.'s as compared to the protein glues was the principal difficulty to be overcome. As compared to the standard test, the experimental tests tended to produce much more rapid deterioration of the U.F.'s than of the protein adhesives. There were no detectable differences in the relative responses of the other variables, so all comparisons were carried out on the basis of the response of each separate adhesive to the different tests. Specimens from each panel were tested in the experimental tests listed in Table I and in the following standard tests:

Standard Tests—4 hours soak followed by 20 hours dry at 75° F., 50 per cent relative humidity

A_1A_2—standard 6-inch by 6-inch test specimen

B_1B_2—experimental test specimen

Test A was the standard cyclic test, which served as the reference index of each panel's durability. A_1A_2 indicates duplicate specimens. This test departed from the specifications in that it was carried on for 50 cycles instead of only 15 cycles.

Test B differed from test A only in that the experimental specimen was used. It was read at each cycle so that both the number of cycles required for a given extent of delamination and also the extent of delamination at any given cycle could be determined.

When the former method was used, the number of cycles passed before one edge delaminated was determined, and then the information from Test B and Test A were combined to give a more stable index of panel durability. This was done within glues, and resulted in no change of the average value of all the panels of a given adhesive as indexed by Test A. This combined index was then used as a basis for evaluation of the experimental tests. A transformation to common logarithms was necessary to stabilize the variances of the standard test, and all subsequent comparisons were made with this transformation.

Transformation of the data from the experimental test was also necessary. In this case, the proper transformation to stabilize the variances was the arcsine transformation. Fortunately, with the arcsine and logarithmic transformations, a linear relationship was indicated for comparison of the experimental test to the standard index. The actual arcsine transformation used was in radians rather than degrees, with y = 2 arcsine (per cent delamination)$^{1/2}$.

As previously stated, the differences in the responses of the U.F.'s versus the protein glues was evident, so all comparisons were carried out on the basis of adhesives. There were sixteen panels made with each adhesive. The U.F. 45–100 proved excessively durable for the purposes of this experiment. It produced so few failures after 50 cycles of the standard test that it had to be omitted from the analysis. No explanation can be offered for this unusual behavior, other than the fact that it appeared to be highly polymerized as indicated by the fact that it was unusually immiscible with water.

The first six experimental tests attempted proved objectionable from either or both of two standpoints—the length of time required to obtain the desired degree of delamination, and the difference in response between the synthetic resins and the protein glues.

Table 1.—EXPERIMENTAL TESTS USED

Test	Temp. (°F.)	Cycle Length: Soak	Cycle Length: Dry	Time Required[2]
R	150	1 hr	3 hr.	12 hr.
S	150	3 hr.	3 hr.	12 hr.
U	125	1 hr.	3 hr.	44 hr.
T	125	3 hr.	3 hr.	36 hr.
D_1[1]	125	1 min.	59 min.	-----
D_2	125	1 min.	1 hr. 59 min.	48 hr.
C_1C_2	150	1 min.	59 min.	24 hr.

[1]Test D_1 was not usable because of insufficient drying.
[2]The time required to obtain approximately 50 per cent delamination for a U.F. 65–100 panel of 10-cycle durability level as indexed by the standard test.

The last column of Table I shows the time required for the given test to produce approximately 50 per cent delamination of a U.F. 65–100 panel with a durability index of 10 cycles as determined by the standard test. The specimens in tests R, S, U, and T were examined at the completion of every cycle and test D_2 at 24 and 48 hours to determine the length of treatment required to produce the desired extent of delamination.

The U.F. 65–100 resin was selected for use as the basis for determining the approximate length of exposure required, and the data on extent of failure were analyzed at this length of treatment. Tests R and S do not satisfy the restrictions imposed by an 8-hour work day, and they also produced a considerable differential between the urea resins and the protein adhesives. Tests U, T, and D_2 produced lesser differences between glue responses but were longer than desired.

Test C_1 appeared very promising, and was therefore duplicated with a second trial, C_2. Figs. 3 and 4 illustrate the relationships between this test and the standard index. The individual panels and a least squares fitting of a linear equation are shown for the U.F. 65–100 to illustrate the variability of the results. The summary graph illustrates the separate linear comparisons obtained for each of the adhesives. It may be noted that the abscissa is a logarithmic scale and the ordinate an arcsine scale.

The cycle number at failure as indicated by the standard index represents the information acquired after 50 cycles, or 50 days, of testing. The cycle number at failure rather than the number of cycles passed before failure (a difference of one cycle) was employed to avoid zero values, which could not be incorporated in a logarithmic transformation. The extreme length of testing time was necessary to obtain sufficient information to provide a durability index for comparison with the experimental tests. Very little information would have been obtained if the test had been terminated at 15 cycles, as the specifications for this test require. The number of edges delaminated as indicated by the experimental test, C, represents the information acquired after only 24 hours of cyclic treatment. As previously indicated (Table 1), the cyclic treatment in test C consisted of 1 minute of soaking and 59 minutes of drying with the air temperature controlled at 150° F. This resulted in a water temperature of 136° F. due to the cooling effect of evaporation, despite the use of a lid over the water container to retard evaporation.

The severity and length of the experimental treatment appear to be very satisfactory insofar as the U.F.'s are concerned. As may be noted from the summary graph, Fig. 3, a panel of 10-cycle quality by the standard test (11 cycles for failure) would be expected to show an average delamination of 6 to 7 edges when tested by the experimental test. With the use of automatic cycling equipment, the 24-hour length of time required for the test is completely satisfactory in regard to the restriction imposed by an 8-hour work day.

In comparing the experimental test to the standard index, only the response of the casein glue shows a statistically significant difference from that of the remaining glues. In view of the other tests attempted, however, it is very possible that the soybean is somewhat less severely affected by this experimental test than are the U.F.'s. The fitting of a least squares linear regression to the data for each glue resulted in the following equations:

U.F. 65-100	$y = 3.5891 - 1.8089\ x$
U.F. 65-150	$y = 3.4834 - 1.8859\ x$
U.F. 45-150	$y = 3.9938 - 2.1332\ x$
Casein	$y = 2.7761 - 2.2357\ x$
Soybean	$y = 3.1892 - 1.8232\ x$
where:	y = 2 arcsine (percent delamination)$^{\frac{1}{2}}$ (y is here expressed in radians rather than degrees)[1]
	x = log (cycle No. at failure)

[1]Hald, A. 1952. Statistical tables and formulas. John Wiley & Sons, Inc., New York. pp 70–71

For each of these equations, the estimates of the dispersion around the line $s_{y \cdot x}$, the standard deviation of the intercept s_a, and the standard deviation of the slope s_b are as follows:

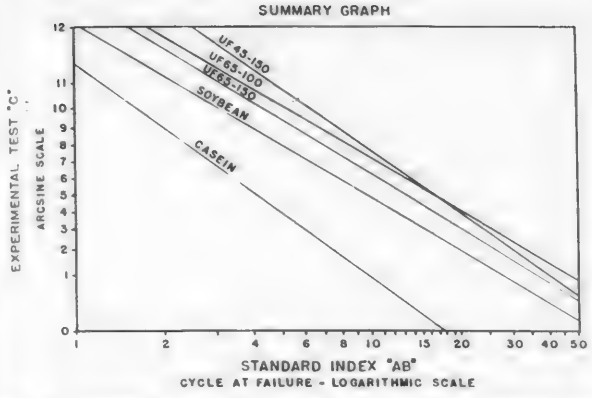

Fig. 3.—Summary graph of all glues, showing the relationship between experimental test C and the present standard test.

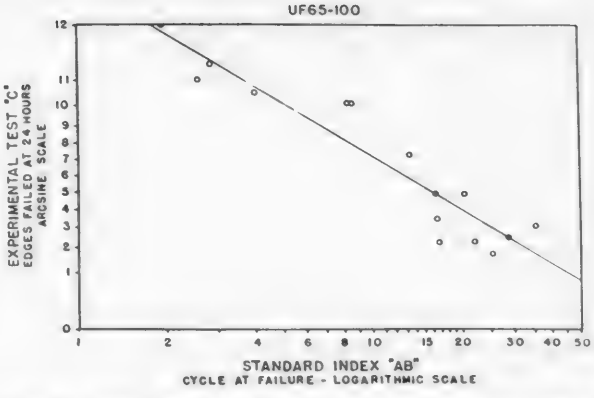

Fig. 4.—Graph showing the data to which the linear relationship of the U.F. 65-100 resin-bonded panels was fitted.

	$S_{y.x}$	S_a	S_b
UF 65-100	.2800	.2015	.1824
UF 65-150	.4572	.3538	.3532
UF 15-150	.7236	.6418	.5657
Casein	.5944	.2028	.4471
Soybean	.1960	.0800	.1400

It must not be assumed that the rather substantial degree of variation displayed by the comparisons between the two test methods may be attributed to the experimental test. The within-panel variances of the experimental test as calculated from the duplicate specimens failed to be significantly greater than those of the standard tests. This test was accomplished by employing the least squares regression of each glue to transfer the variance of the standard test to its equivalent in the experimental test, and then making the usual "F" test between this transferred variance and the actual experimental test variance.[4] Although not statistically significant, the indications were that the experimental test may be slightly less sensitive than the standard test. This indication is of minor importance, however, when one considers the fact that, in this instance, the standard test was conducted for 50 cycles rather than the conventional 15 cycles.

Summary

The results of this investigation clearly indicate the feasibility of a 24 hour test for determining the durability of Type II hardwood plywood. Within one day, the experimental test provides as much information regarding plywood durability as is gained by 50 days of testing with the standard cyclic test, and does so with comparable sensitivity. If the standard test is conducted for only 15 cycles, as specified, the comparison becomes even more favorable to this experimental test. Some concession may be required in favor of those glues which exhibit less sensitivity to temperature than do the urea-formaldehyde resins. This concession may be no greater, however, than that currently being made in favor of temperature-sensitive resins by the employment of a room temperature test.

Future Work

This investigation is being continued with the support and cooperation of the Hardwood Plywood Institute, and precise specifications regarding testing variables and equipment will be made available as soon as possible.

Discussion

Claus Sutor (Aetna Plywood & Veneer Co.): I am curious to know if definite inferior glue lines have been investigated?

Mr. Hart: We have made inferior panels in the laboratory to get comparisons.

Mr. Sutor: Is the test suitable for use in testing to meet acceptance test criteria?

R. F. Blomquist (U. S. Forest Products Laboratory): The 10-cycle test is not normally used in glue comparison as such, but is used primarily to determine quality of glue bonds as made in plywood. Experience indicates that laboratory efforts to make mediocre panels for such comparison tests are difficult. This work indicates remarkable progress in increasing the speed and efficiency of testing glue joints on plywood.

R. W. Peterson (Canadian Forest Products Laboratories): Was water used in the oven, and what was the temperature used?

Mr. Hart: Water was in the oven, and final air temperature was 150°. Water temperature uncontrolled was 136°.

A. A. Marra (University of Michigan): It is a distinct pleasure to see statistical power combined with technology to solve a problem in testing of glued assemblies where variables are so many and so elusive as to discourage all but the most persistent researcher. In making observations with a new specimen, it is logical to include observations on standard specimens to provide points of comparison. The new procedure is sometimes criticized, however, if it does not conform to the results shown by the old. Such criticism should not influence the validity of the new test if the old is as arbitrary as that used in the present study. Who is to say which method is giving the most accurate results? If the new method magnifies and accelerates differences, there are important virues, and what we need now is the experience to properly interpret them in the light of subsequent performance.

[4] Mandel, J., and R. D. Stiehler. 1954. Sensitivity—a criterion for the comparison of methods of test. Jour. of Research NBS 53(3): 155-159.

A Rapid Delamination Test for Plywood[1]

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The rapid delamination test is based primarily upon an automatic delamination machine developed by the author. The machine test method is easy, fast, and not inhibited by the 8-hour working day. The machine is a practical tool that has application to quality control and research. Test results may be obtained on panels with poor glue bonds in one day.

CONSIDERABLE EFFORT AND INTEREST in recent years have been directed at devising and improving existing test methods for evaluating glue bonds in plywood. Existing test methods for evaluating glue bonds are grouped into two broad classifications in this paper. The first classification is the determination of joint strength in the plywood glue bond. This is done by mechanical test methods that apply external forces such as tension (1)[2] and cleavage (16) forces to the plywood construction. The second classification is the quality of the glue bond. Quality of glue bond is determined by the delamination or standard cold-soak test (2, 4) and the practice of reading wood failure.

The problem of any of these short-term or accelerated test methods is to duplicate the conditions that are encountered in service. The delamination or cold-soak test is designed to duplicate the natural weathering process. Accelerated tests are more severe than what is encountered in service conditions. The purpose of accelerated severity is to get an indication of the resistance of the plywood to the service conditions in a short time, the principle being that if the plywood can withstand the accelerated test the panel will possess durability in service.

Within the broad classifications of strength and quality of plywood glue bonds, there is a differentiation as to the uses of the plywood construction. Completely waterproof glue bonds are intended for use in exterior service conditions, such as are encountered in the hulls of boats. Water-resistant glue bonds are intended for use where the panel will become wet infrequently. This latter type of glue bond, along with the dry bonds, is used primarily in interior service conditions, such as are encountered in furniture and woodworking.

Fig. 1.—The delamination machine.

The research work presented in this paper was limited to interior glue bonds and the determination of their quality. The new, rapid delamination test presented in this paper was first evaluated on Douglas-fir plywood made under optimum gluing conditions. The results of the new delamination test were compared to the standard cold-soak test and two other accelerated delamination tests. Since the results were favorable, the new delamination test was compared to other methods of glue bond evaluation (wood failure, shear strength, and cleavage strength) in a controlled experiment where good and poor glue bonds were studied. This latter comparison was limited to bonds of mahogany to mahogany and mahogany to Douglas-fir.

Hardwood-faced plywood with a softwood core presents an interesting problem to the tester. Since the construction is neither a hardwood nor a softwood plywood, this unique construction does not fall under the Commercial Standard C.S. 45–55 (4) for softwood plywood or C.S. 35–49 (3) and C.S. 35–56 (3) for hardwood plywood. Most of the mills that are producing the hardwood-faced plywood are now or have been members of the Douglas Fir Plywood Association. The commercial standard used by the Douglas Fir Plywood Association is C.S. 45–55 (4). It is only natural for the mills to turn to this standard with which they have been familiar through long usage to evaluate glue bonds of mahogany to Douglas-fir.

Limitations of Commercial Standard 45–55 to the Testing of Mahogany-Faced Plywood Made on The West Coast

The limitations that will be discussed will deal primarily with the testing of interior plywood. Haigh (11), in an article concerning the evaluation of interior plywood, proposed the "D" test, which incorporated a 1-inch by 10-inch specimen. The softwood plywood commercial standard requires the use of a 6-inch by 6-inch test specimen. Because of its size, the 6-inch-square specimen does not become thoroughly wet or thoroughly dry in the delamination cycle. An advantage of the smaller test specimen is the greater number of test specimens per area sampled. In the 1-inch by 10-inch specimen, the stresses of wetting and drying will be at their maximum because of the thorough wetting and drying of the specimen. Thus the maximum ability of the glue bond to resist the internal stresses of delamination is tested.

Blomquist (8) noted the effect of heat upon phenolic resin glues in the boil test. Strength of the glue line is increased by the advancement of the resin with heat. The general practice of pressing plywood panels glued with resin adhesives is to "hot stack" the panels to increase the production and efficiency of the hot press. When taken from the hot press, the panels have an incompletely cured glue line. Mois-

[1] A 1957 Wood Award Entry. The paper is a condensation from an original thesis entitled "A Comparison of Four Methods for Evaluating Philippine Mahogany-Faced West Coast Interior Plywood", submitted by the author for a Master of Forestry degree from the University of Washington.

[2] Numbers in parentheses refer to the Literature Cited at the end of this paper.

The Author: Oliver Campbell received a BS degree in forestry from Iowa State College in 1953. He entered the University of Washington in January, 1956, and was awarded the Lawrence Ottinger Forest Products Fellowship (given by U. S. Plywood Corp.) for the 1956-1957 school year.

mum cure is possible when the best hot-stacking practices are followed.

Panel acceptance by the wood-failure criterion has received a great deal of attention since the innovation of plywood. Truax (20) discussed wood failure as a means of evaluating glue bonds in 1929. He showed that the strength of the wood greatly affects the amount of wood failure when casein and animal glues are used. With the strength of the glue bond being equal or greater than that of the wood, low-strength woods show a high percentage of wood failure, and the high-strength woods show a low percentage of wood failure. Truax also indicated that the combination of wood failure and joint strength would be a measure of glue bond effectiveness. Bergin (6), working with Canadian woods, showed the glueability differences of different species in support of Truax.

Perkins (17) in 1950 presented a relationship between wood failure and long-time exposure of panels of plywood on test fences. The plywood was made of only one species, Douglas-fir. In the discussion that followed the article, it was pointed out that sometimes a difference exists between readers of wood failure, and this difference becomes a problem in obtaining consistent results.

More recently, Northcott (16) criticized the wood-failure method of evaluation because it is not universally applicable as a method of evaluating other species. A glueline cleavage test advocated by Northcott is a method of evaluation that can be understood and performed throughout the world. The point at issue here is the human element that is involved when reading wood failure. The wood-failure values are the result of the judgment of the reader of wood failure, which is periodically checked against a standard set of wood-failure specimens. This standard set of wood-failure specimens was devised by the Douglas Fir Plywood Association for their quality-control program.

In a construction such as the mahogany-faced plywood with a Douglas-fir core, hardwood and softwood species are combined. In the hardwood plywood commercial standard, the wood-failure minimum values vary with the average shear strength, which in turn varies with the density of the species used in the plywood. The high-density species give much lower wood failure than the low-density species. Basically, the nature of the two dissimilar veneers being bonded in the mahogany-faced plywood reflects the general structural differences in the anatomy of a Gymnosperm and Angiosperm. The end result is that a different wood-failure criterion must be developed for the mahogany-faced plywood.

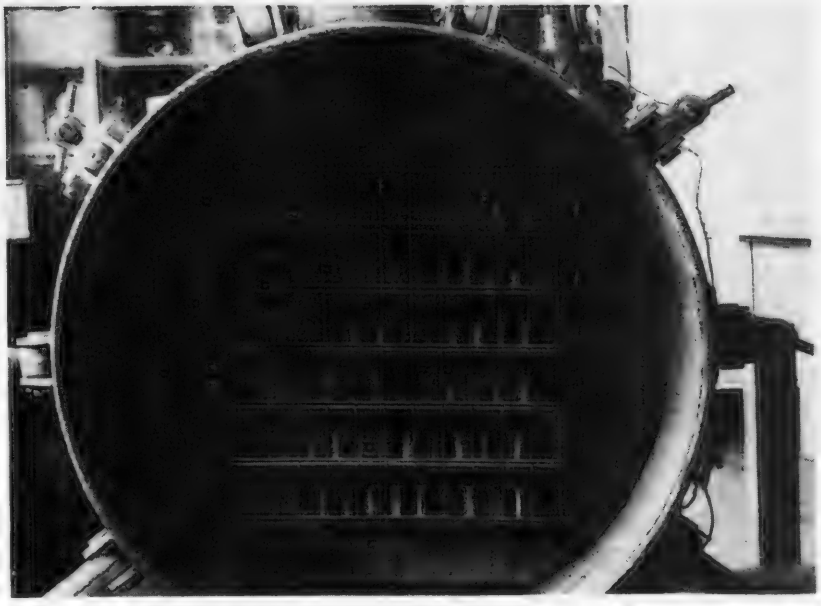

Fig. 2.—Specimen placement in the delamination machine.

Concerning the tension-shear test for glueline evaluation, the American Society of Testing Materials Standard (1) states that the wood failure will be read and recorded. This standard does not state how the wood failure will be evaluated. There is no mention of what wood failure will constitute service conditions. The testing standard is set up primarily for a uniform procedure of testing as an aid in comparing test results. The method of evaluation must also be uniform, however, or the test method loses its significance to the consumer and tester.

Evaluation of white-speck veneer in plywood was studied by Erickson, Bryant and Blanchard (10) in an effort to determine the best method of fair evaluation of the quality of white-speck plywood. Again, the problem of wood failure presented itself as a difficult method for achieving uniformity of results because of the white-speck pockets.

From the preceding discussion it seems that the commercial standard for softwood plywood has definite limitations for testing and comparing the test results of mahogany-faced plywood made on the West Coast. The controls necessary for uniform precision testing of interior glue bonds that are lacking in the present commercial standard are as follows:

1. The absence of control over the lathe-check orientation in testing with the tension-shear specimen.
2. Insufficient control over the rate of drying of the specimens by standardizing the velocity and relative humidity of the drying air.
3. Insufficient control of the water temperature and the drying air temperature in the cold-soak test.
4. The absence of a uniform basis for the evaluation of wood failure.

Delamination Machine

Explanation of Machine: A disadvantage of the cold-soak test in evaluating interior plywood is the long time required for the test. For this reason, the delamination test has not been an effective quality-control tool in the plywood industry. The poorly glued plywood panels probably would have been placed in a building start by the time the present cold-soak test results are completed. The cold-soak test varies in length from ten to fifteen days, depending upon the number of cycles the tester requires to insure the quality of the plywood. It takes one day to complete one cycle of a soak for 4 hours at room temperature followed by drying at room temperature for 20 hours. Generally, the number of test cycles is ten, with credit being given for the cycles passed by the test specimen. It is difficult to put this type of test result on a quality-control chart or to subject the results to a statistical analysis.

A delamination machine (Fig. 1) places the soaking and wetting cycles on an automatic basis. Automation is achieved by a time clock, which activates the controls at specified time intervals. Specimens to be tested are placed in a rack, which is inserted in a horizontal, cylindrical tank. Water enters the tank when a ¾-inch electric

solenoid opens the normally closed inlet valve. The tank drains when another solenoid valve relaxes to a normally open position. The level of the water in the tank for the soak is controlled by a mercury-float switch.

The drying cycle is controlled by another mercury-float switch, which regulates the fan and heating elements. The temperature of the drying air is regulated by a thermostat, and the water temperature is controlled by a mixing valve. Exhaust and inlet vent openings allow control of the rate of drying. Combinations of various amounts of heat are possible for the drying cycle. The time clock is set with trippers to turn off and on, thus providing the flexibility for the various schedules. The electric solenoid valves are protected by "Y"-traps, which catch the particles that would prevent the valve from functioning properly.

The 1-inch by 10-inch specimens recommended by Haigh (11) are placed in a wire rack in the machine (Fig. 2) and held in position by rods and spacers. These specimens are held in a semi-fixed position to prevent the blocking of air flow between the positioned specimens. Baffles are used to direct the air between the specimens after the fan blows the air over the heaters. Between the baffles there is sufficient space to hold 90 test specimens of three-ply plywood.

It appears that the delamination machine overcomes the inadequacies of the present commercial standards by controlling the air and water temperature, rate of drying, and, automatically, the time of cycle.

If a cycle time of six hours is used with automatic regulation, the delamination machine is not restricted by an 8-hour working day or weekend delays. Thus the potential of the machine is apparent for obtaining the test results faster and more easily.

Comparison of Delamination Machine to Other Delamination Test Methods

For comparing the performance of the delamination machine to other delamination test methods of evaluating interior plywood, an experiment was performed in conjunction with the Seattle Technical Service Branch of Reichhold Chemicals, Inc.

Two experiments were performed on the specimens from the same 13/16-inch five-ply, Douglas-fir plywood panels. The experimental design involved two statistical factors with three replications. The first factor was glue, and the second factor was test methods. Eight glues were used in the experiment: four blood-soybean glue mixes, two soybean glue mixes, one

Table 1.—MACHINE DELAMINATION RESULTS[1]

Glue	Test 1 12 cycles 2 hr. Soak at 100° F. 4 hr. Dry at 145° F.	Test 2 12 cycles 2 hr. Soak at 100° F. 2 hr. Dry at 145° F.	Test 3 12 cycles 2 hr. Soak at 65° F. 4 hr. Dry at 145° F.	
A Blood-Soybean	12.5	7.4	7.7	Total 89.4%
	15.3	9.1	8.1	Av. 9.9%
	14.8	5.4	9.1	Intact 90.1%
	42.6	21.9	24.9	
B Blood-Soybean	22.7	14.8	16.2	Total 126.4%
	7.5	9.6	15.0	Av. 14.0%
	17.0	8.0	15.6	Intact 86.0%
	47.2	32.4	46.8	
C Blood-Soybean	10.5	15.6	6.7	Total 64.8%
	5.7	3.1	2.8	Av. 7.1%
	8.5	5.1	6.0	Intact 92.9%
	24.7	23.8	15.5	
D Blood-Soybean	2.8	14.5	9.4	Total 77.5%
	4.2	18.2	5.1	Av. 8.3%
	9.4	3.2	10.8	Intact 91.7%
	16.4	35.9	25.3	
E Soybean	46.4	50.5	38.1	Total 252.8%
	27.3	24.2	32.6	Av. 28.1%
	15.3	7.4	10.8	Intact 71.9%
	89.0	82.1	81.5	
F Soybean	12.2	6.2	11.7	Total 117.8%
	6.5	10.2	8.2	Av. 13.1%
	20.2	29.0	13.6	Intact 86.9%
	38.9	45.4	33.5	
G Phenolic	1.4	2.0	1.7	Total 25.3%
	1.4	3.4	2.6	Av. 2.4%
	1.4	6.5	5.4	Intact 97.6%
	4.2	11.9	9.7	
H Urea	23.8	19.3	26.7	Total 239.2%
	42.8	25.8	22.7	Av. 26.6%
	31.8	17.9	28.4	Intact 73.4%
	98.4	63.0	77.8	
Total	361.4%	316.4%	315.0%	
Av.	15.1%	13.2%	13.1%	

[1]Values represent the amount of delamination expressed as a percentage of the total glue line available for delamination.

Table 1a.—ANALYSIS OF VARIANCE MASTER TABLE FOR MACHINE DELAMINATION TESTS

Degrees of freedom	Net sum of squares	Mean square	Variance ratio	Significance
71 Gross S.S.	8,571.03			
7 Glues	5,160.71	737.24	10.77	99%
2 Tests	58.05	29.02	.42	N.S.
14 Glues by tests	409.92	29.28	.43	N.S.
43 ERROR	2,942.35	68.43		

[1]Just Significant Difference at 95% level of probability is 7.9;
Just Significant Difference at 99% level of probability is 10.6.

Table 1b.—JUST SIGNIFICANT DIFFERENCE BETWEEN GLUES

	Blood-soybean glue mixes				Soybean glue		Phenolic	Urea
	A	B	C	D	E	F	G	H
	90.1%[1]	86.0%	92.9%	91.4%	71.9%	86.9%	97.1%	73.4%
A 90.1%					(−)[2]			(−)
B 86.0%					(−)		(+)	(−)
C 92.9%					(−)			(−)
D 91.4%					(−)			(−)
E 71.9%	(+)	(+)	(+)	(+)		(+)	(+)	
F 86.9%					(−)		(+)	(−)
G 97.1%		(−)			(−)	−[3]		(−)
H 73.4%	(+)	(+)	(+)	(+)		(+)	(+)	
Total	2	1	2	2	−6	1	4	

[1]Values represent the per cent of panel intact after the test.
[2]The symbol is used to denote a significant difference at the 99% level of probability. A minus sign signifies that the top per cent is significantly smaller than the side value.
[3]The absence of parentheses denotes a significant difference at the 95% level of probability.

Table 2.—RESULTS OF EXISTING DELAMINATION TESTS[1]

Glue	Regular "S" test	Modified "S" test	Cold soak		
A Blood-Soybean	15	11	13	Total	65.0%
	12	7	1	Av.	7.2%
	2	3	1	Intact	92.8%
	29	21	15		
B Blood-Soybean	10	8	1	Total	47.0%
	6	6	1	Av.	5.2%
	9	5	1	Intact	94.8%
	25	19	3		
C Blood-Soybean	2	3	1	Total	22.0%
	2	4	1	Av.	2.4%
	4	4	1	Intact	97.6%
	8	12	3		
D Blood-Soybean	10	4	1	Total	27.0%
	1	5	1	Av.	3.0%
	2	2	1	Intact	97.0%
	13	11	3		
E Soybean	32	25	97	Total	425.0%
	36	29	100	Av.	47.2%
	12	4	90	Intact	52.8%
	80	58	287		
F Soybean	1	3	10	Total	178.0%
	8	11	30	Av.	19.8%
	29	23	62	Intact	80.2%
	38	37	103		
G Phenolic	2	1	1	Total	11.0%
	1	1	1	Av.	1.2%
	2	1	1	Intact	98.8%
	5	3	3		
H Urea	53	64	43	Total	473.0%
	55	79	50	Av.	52.6%
	60	68	1	Intact	47.4%
	168	211	94		
Total	365%	371%	511%		
Av.	15.2%	15.4%	21.3%		

[1]Values represent the amount of delamination expressed as a percentage of the total glue line available for delamination.

Table 2a.—ANALYSIS OF VARIANCE MASTER TABLE FOR EXISTING DELAMINATION TESTS

Degrees of freedom		Net sum of squares	Mean square	Variance ratio	Significance
71	Gross S.S.	46,406			
7	Glues	27,680	3,954.3	36.58	99%[1]
2	Tests	565	282.5	2.61	N.S.
14	Glues by tests	13,514	965.3	8.93	95%[2]
43	ERROR	4,647	108.1		

[1]Just Significant Difference at 99% level of probability is 13.3;
[2]Just Significant Difference at 95% level of probability is 9.9.

Table 2b.—JUST SIGNIFICANT DIFFERENCE BETWEEN GLUES

	Blood-soybean glue mixes				Soybean glue		Phenolic	Urea
	A	B	C	D	E	F	G	H
	92.8%[1]	94.8%	97.6%	97.6%	52.8%	80.2%	98 8%	47 4%
A 92.8%					(−)[2]	−[3]		(−)
B 94.8%					(−)	(−)		(−)
C 97 6%					(−)	(−)		(−)
D 97.0%					(−)	(−)		(−)
E 52.8%	(+)	(+)	(+)	(+)		(+)	(+)	
F 80.2%	+	(+)	(+)	(+)	(−)		(+)	(−)
G 9 8%					(−)	(−)		(−)
H 47 4%	(+)	(+)	(+)	(+)		(+)	(+)	
Total	3	3	3	3	−6	−3	3	−6

[1]Values represent the per cent of panel intact after the test.
[2]The symbol is used to denote a significant difference at the 99% level of probability. A minus sign signifies that the top per cent is significantly smaller than the side value.
[3]The absence of parentheses denotes a significant difference at the 95% level of probability.

urea glue mix, and one phenolic glue mix. To prevent blows in the hot press, Douglas-fir veneer was conditioned at 110° F. for a period of 30 hours to obtain a moisture content of 3 to 5 per cent. The veneer was cooled before the glue was spread and the test panels were pressed. Three 1-foot by 2-foot panels were made for each glue. Test panels were "hot stacked" to simulate mill conditions in a hot stacking box of the type used by the major glue companies for laboratory work.

The test methods in use for glue bond evaluation that were used in one of the experiments are as follows: the "S" test consisted of four cycles of a 16-hour cold soak followed by drying at 145° F. for eight hours; a modified "S" test consisted of two cycles of a 145° F. soak for four hours followed by drying at 145° F. for 20 hours; the standard cold-soak test of 15 cycles consisted of a 4-hour soak at room temperature followed by drying at room temperature for 20 hours.

The delamination tests in the second experiment with the delamination machine consisted of the following: the first test included 12 cycles of a 2-hour soak at 100° F. followed by drying at 145° F. for four hours; the second test consisted of 12 cycles of a 2-hour soak at 100° F. followed by drying at 145° F. for two hours; the third test included 12 cycles of a 2-hour soak at 65° F. followed by drying at 145° F. for four hours. These cycles were chosen to obtain possible combinations that can easily be adapted to the time clock and still maintain maximum soaking and drying.

The test specimens were obtained alternately from the test panels. The amount of delamination was expressed as a percentage of the total glue line available for delamintion.

Delamination Machine Results

In both experiments the effect of the glues proved to be highly significant statistically by the analysis of variance (19), while the test methods did not differ appreciably from each other. A qualitative comparison of the two experiments can be made by comparing the totals of each glue mix in the Just Significant Difference[3] between glues in Tables 1B and 2B. The totals for each experiment are approximately the same for each glue mix used in the experiment. Slight differences that are present are due to the interaction of the glue effect and the test effect in the experiment with the cold-soak test, "S" test, and modified "S" test. This interaction was

[3] Just Significant Difference values represent the minimum difference between averages that is significant at a given level of probability.

caused by a soybean glue mix reacting with the cold-soak test as shown in Table 2. It is apparent from these results however, that the delamination machine on an accelerated basis is as sensitive to poor glue bonds as are the existing delamination methods of interior glue bond evaluation.

No difference was found in the amount of delamination because of the position of the specimens within the machine. There is a difference of approximately 12 inches of water from the top tray to the bottom tray of specimens. It is also noted that the hot air of the drying cycle might concentrate in the upper trays. After statistical analysis of two test runs, however, no difference was found in the amount of delamination due to placement.

A relation of the number of test cycles completed to the amount of delamination for the 2-hour soak at 65° F. followed by drying at 145° F. for four hours is presented in Figure 3. The purpose of the graph is to show that the greatest average amount of delamination per unit of time in cycles occurred in the first four cycles or in one day of testing.

The test cycle of a 2-hour soak at 65° F. followed by drying at 145° F. for four hours was the test method that gave the most uniform results. This is shown in Table 3 by the smallest error term and the largest F ratio for test 3. A partial vacuum created in the wood cells by the cold water surrounding the specimens containing hot expanded air in the cells apparently pulled the water into the wood more uniformly than where hot water was used. The other test methods depended upon the lathe checks for water penetration.

Experimental Procedure for Comparing Delamination Machine to Other Methods of Evaluating Interior Plywood.

Design of Experiment: For comparing the delamination machine to other methods of evaluating interior plywood, a 5-factor experiment was performed. The five statistical factors, each at two levels, were as follows: glues, assembly times, density of face plys, face types, and core species.

The two levels of glues studied were a wheat-flour-extended urea glue and a furafil-extended phenolic glue. The urea glue had an extension ratio of one part resin to one part of wheat flour, while the phenolic glue had a ratio of three parts of resin to one part of furafil. These two glues are used considerably for glue bonds of Philippine mahogany-faced plywood made in the Puget Sound area of

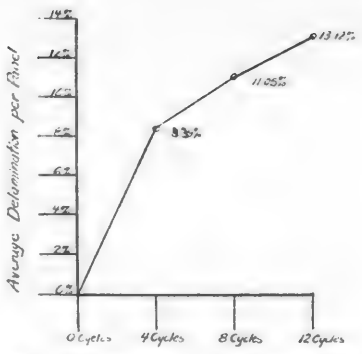

Fig. 3.—Comparison of delamination to number of test cycles. Each cycle consists of 2 hours soak at 65° F., followed by 4 hours drying at 145° F. Values represent average of 24 panels of 13/16-inch, 5-ply, Douglas-fir plywood.

Washington. An optimum and an extended assembly time for both glues were the two levels of assembly time. The extended assembly time was a 5-minute extension beyond the maximum recommended for each glue. The optimum assembly time was 10 minutes, while the extended assembly time was 25 minutes of closed assembly time for both glues.

The two levels of face type were rotary and sliced Philippine mahogany veneer. The face veneer was 1/10 inch in thickness for both veneer types. The two levels of density for each face veneer type were an average specific gravity of 0.40 on an oven-dry volume basis for the low density and 0.57 for the medium-density veneer. These density classifications within each veneer type were obtained by separating the veneer by weight at the same moisture content. The specific gravity determinations were made on the average panels for the separate weight populations.

The two levels of core species studied were Philippine mahogany and Douglas-fir. The core was 3/16 inch thick for both species. A 3/8-inch-thick test panel was formed by the combination of a 3/16-inch core and 1/10-inch faces. Face plys were matched to insure a balanced construction, while the cores were matched between densities in the same face type.

The experiment was repeated separately for all the factors except the glue factor. The same glue mix was used when repeating the other factors. A resulting statistical block effect was represented by two test panels. Since all the factors were not replicated in A and B, the result cannot be called a pure replication. Therefore, each cell in the presentation of data in Table 4 represents an A and B block. Each block in turn represents one panel.

Acquisition and Preconditioning of Veneer: The veneer for the experiment was selected at random from the United States Plywood Corporation plant in Seattle, Washington, from many Philippine mahogany logs. Some attention was paid to veneer color because it is a partial indication of density. The very light and extremely dark veneers were not selected since they were the exception rather than the rule. Different driers at about 350° F. maximum temperature had previously conditioned the veneer before selection.

The veneer was separated by weight into two classes. The population of weight classes of the veneer with each face type was mutually exclusive for each classification. The weight populations were analyzed statistically and determined to be different between each face type and approximately the same between densities. It is therefore possible to compare directly the low-density rotary-face type with the low-density sliced-face type. The extremes of the weight populations were omitted when making the selection for the test panels.

The average veneer weight for each density was sampled for specific gravity determinations. Average specific gravity based on oven-dry volume basis is as follows:

Mahogany Face				Core Species	
Sliced		Rotary			
Low	Medium	Low	Medium	Mahogany	Douglas-fir
0.39	0.55	0.40	0.59	0.59	0.51

The veneer was measured with a micrometer to eliminate any veneer that was not 1/10-inch for faces and 3/16-inch for cores.

The veneer was conditioned before gluing at 110° F. for a period of 48 hours to bring the moisture content to 3 to 5 per cent to prevent blows

Table 3.—COMPARISON OF ANALYSIS OF VARIANCE OF TESTS TO DETERMINE OPTIMUM CYCLE (DELAMINATION MACHINE EXPERIMENT)

	Test 1 12 cycles 2 hr. Soak at 100° F. 4 hr. Dry at 145° F.		Test 2 12 cycles 2 hr. Soak at 100° F. 2 hr. Dry at 145° F.		Test 3 12 cycles 2 hr. Soak at 65° F. 4 hr. Dry at 145° F.	
Gross sum of squares	8,945.62		6,483.12		6,351.90	
		F Ratio		F Ratio		F Ratio
Glues	8,018.69	8.65	5,432.27	5.17	5,867.34	12.11
ERROR	926.93		1,050.85		484.56	

Table 4.—SHEAR TEST RESULTS

		Douglas-fir core				Mahogany core C				
		Sliced face		Rotary face F		Sliced face		Rotary face F		
		Low density	Medium density D	Low density	Medium density D	Low density	Medium density D	Low density	Medium density D	
Phenolic glue	Optimum assembly time	118	113	106	111	108	117	122	109	A
		104	101	111	130	106	137	115	115	B
		222	214	217	241	214	254	237	224	Sum
	Extended assembly time	98	91	110	111	100	121	105	129	A
		102	124	104	108	117	100	116	107	B
	A	200	215	214	219	217	221	221	236	Sum
Urea glue	Optimum assembly time	99	109	120	111	110	114	100	97	A
		109	133	101	126	92	96	122	109	B
		208	242	221	237	202	210	222	206	Sum
	Extended assembly time	92	80	98	95	109	106	98	100	A
		103	103	117	106	111	128	114	122	B
	A	195	183	215	201	220	234	212	222	Sum

Values represent totals of eight tension shear specimens in pounds per square inch times 0.1.
Total of A and B = 6996

Gross sum of squares	772,470
− Correction term	764,750
Net sum of squares	7,720

the hot press. Before it was glued, the veneer was stickered and allowed to cool at room temperature to prevent precure of the glue.

Preparation of Test Panels: The selection of the core and faces that were to be made into the test panel was done at random through the weight populations. The faces of the panel were matched from the same 13 by 25-inch veneer sheet. The 13- by 25-inch core veneer was matched between densities of face veneer in the same face type. The test panels were approximately 13 inches square after they were pressed. The panels were numbered in a manner to prevent any personal bias of the tester. The panel made was essentially free of stresses due to unbalance.

The glue mixes were prepared according to the manufacturers' instructions in their own glue lab so that the best conditions of gluing were present. The spreader was adjusted to 66 pounds of glue per 1,000 square feet of double glue line. This spread was a compromise between the additional five pounds of spread that is recommended for hardwood cores. Test panels were pressed at 200 pounds per square inch of panel for the required time and temperature. A potentiometer was used to check the temperature of the press platens when the press was closed. The only factors that were varied in the glue laboratory were the assembly time and the kind of glue.

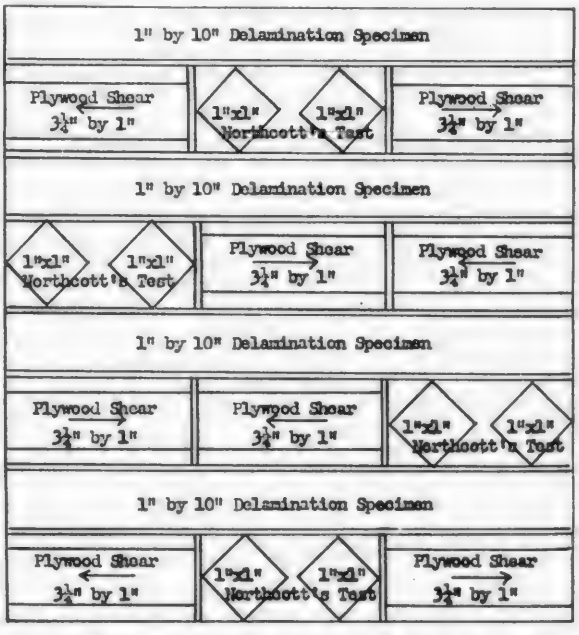

Fig. 4—Description of sampling plan. Test panels were 13 inches square, with the face grain direction parallel to the arrows in the shear specimens. These arrows were pointed toward the saw fence when the specimens were kerfed, with the result that half were pulled closed with regard to the lathe checks of the rotary core.

The panels were hot stacked after pressing in the hot stacking box of the type used by the major glue companies for laboratory work. After two hours, the panels were taken from the hot stacking box and allowed to cool slowly overnight at room temperature while in plastic bags. Two hours is recommended as the minimum time for hot stacking in the plywood mills.

The placement of the panels in the press was predetermined to prevent the effect of press opening from entering the experiment. The A block panel was placed in a separate press opening from the B block panel, while the rest of the panels were placed at random in the press. The spreader was a Black Bros., with 24-inch double rolls with diamond grooving on both spreader rolls.

The phenolic glue was cured in the press for three minutes at 285° F., and the urea glue was cured for three and one-quarter minutes at 260° F.

Preparation and Post-Conditioning of Specimens: The test panels were allowed to reach room moisture content and temperature for three days before the panels were cut into the test specimens. A plastic template, which was placed on the panels according to the grain direction, was used as an aid to mark and number the specimens. Fig. 4 shows the sampling plan for the panel to be cut into test specimens.

A table saw and band saw were used to cut the panel into the test specimens. Four delamination 1-inch by 10-inch specimens, eight 1-inch-square specimens on a 45° angle, and eight standard tension-shear specimens were obtained from each panel. The lathe-check orientation was predetermined in the shear specimens to pull one half of the specimens open and the other one half of the specimens to pull closed. Five-hundred and twelve shear and cleavage specimens and 256 delamination specimens were obtained from the 64 test panels.

The shear specimens and cleavage specimens were conditioned in a constant humidity of 50 per cent at 23° C. for five days prior to testing. (This conditioning is recommended in the A.S.T.M. (1) as a standard temperature and humidity condition for comparable results.) A moisture content of 6 per cent on an oven-dry basis was measured in the specimens at the time of testing. The delamination specimens were not conditioned, since they were placed in the delamination machine for the beginning soak portion of the cycle.

Test Methods

Delamination Machine Test: The 256 delamination specimens were di-

Fig. 5.—Measuring the delamination produced.

vided into four groups of 64 specimens. A specimen from each panel was placed in each of the four groups. Each group was run separately in the machine at the same conditions.

The 1-inch by 10-inch specimen gives 91 per cent of the glue line exposed in a 6-inch square specimen of three-ply plywood. Because the core is cut to a length of one inch, greater water penetration of the core is possible. The resulting effect is a greater swelling and shrinking in the test specimen. This was evidenced by the extent of lathe checks opening to relieve the internal stresses of swelling and drying. It seems that the 1-inch by 10-inch specimen gives a much more drastic test than is possible with the 6-inch square specimen.

Delamination was measured and recorded for the fourth, eighth and twelfth cycle. The lineal inches of delamination were measured after a probe was used to determine the delamination (Fig. 5). The amount of delamination in inches was expressed as a percentage of the 44 inches of total glue line exposed. The value recorded for the 12 cycles completed was used in the statistical analysis.

The test cycle was a 65° F. soak for two hours followed by drying at 145° F. for four hours. This cycle was chosen previously for the uniform test results. Each group of 64 was run through the same cycle so that any inherent variability of the machine test cycle would be averaged out in the groups. The specimens were placed in the same position for each group.

Northcott's Cleavage Test: The test set-up is shown in Figs. 6 and 7. The essentials of the cleavage test devised by Northcott are as follows: a 90° knife that forms a 45° angle with the perpendicular, a self-aligning jig to bring the knife equally on the specimen, and a uniform rate of loading. A rate of loading of 1 inch per minute was used in the testing. The tests were conducted on a National Forge testing machine. After the specimen was placed on the aligning jig, an ocular judgment was made to determine whether the knife would start on the glue line. According to the nature of the specimen after the knife is started, the knife is directed into the glue line. One square inch of glue line was tested for each glue line in the specimen, which resulted in 16 values for each panel.

A deviation from the original test procedure was the absence of greasing the knife before testing to minimize the frictional component. A reduction of the thickness after the first glue line was tested was also a source of variation not present in the original test.

Plywood Tension–Shear Test: The standard plywood tension-shear specimen was used. The specimen was three and one-quarter inches in length, with two saw cuts to the farthest glue line, one on each side of the specimen. One square inch of glue line is tested in shear. The lathe-check orientation was predetermined to pull one half of the specimens open and the other one half of the specimens closed.

The shearing machine used was manufactured by Monsanto Chemical Company. The clamps that grip the specimen are air operated, and water pressure is used to regulate the loading. The loads necessary to shear the one square inch of glue line to failure were recorded to the nearest ten pounds on the gage. The panels to be sheared were chosen at random.

Fig. 8.—Determination of wood failure

Wood Failure Test: Because the plywood panels were not Douglas fir plywood, the standard set of wood-failure specimens used by the glue companies through the Douglas Fir Plywood Association was not appropriate. The nature of the glue bonds such as mahagony to mahagony and mahagony to Douglas-fir yielded different wood failures. To standarize the reading of wood failure to prevent personal bias, a template grid was used. The grid was one inch square with 20 rectangles of equal size, each representing five per cent of wood failure.

The amount of gross wood failure was measured by counting the small squares representing five per cent of wood failure. The amount of credit to be given to the minute wood failure was up to the judgment of the reader of wood failure. Depending upon the individual specimen, an additional five per cent was given for the minute wood failure. The minute wood failure value was added to the gross wood failure to obtain the total wood failure for the specimen.

The determination of wood failure is shown in Fig. 8.

Results and Conclusions

Results of the Four Tests: The results of each of the four tests were tabulated and totaled for each block.

Fig. 6—Set up for the Northcott Cleavage Test.

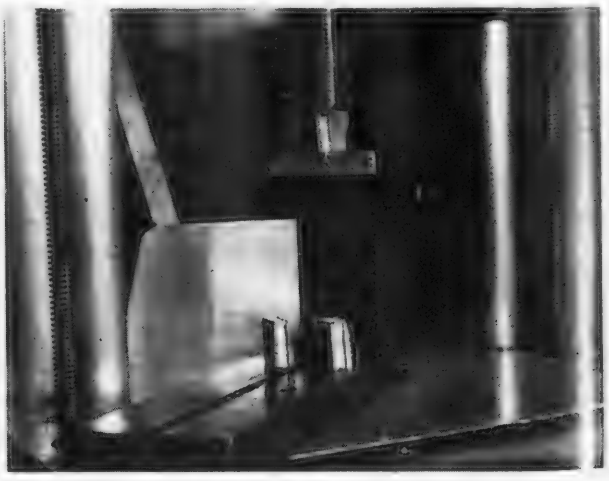

Fig. 7.—Specimen being cleaved.

This total was placed in the A row and B row in each cell in Tables 4, 5, 6 and 7, with the sum of the blocks also placed in the cells. Table 8 gives the summary of the individual master tables of each test.

The conclusions are based on the summary master table and Figs. 9, 10, 11, and 12, which graph the main effects and interactions as an aid to the conclusions.

Table 5.—NORTHCOTT'S TEST RESULTS

		Douglas-fir core				Mahogany core C				
		Sliced face		Rotary face F		Sliced face		Rotary face F		
		Low density	Medium density D	Low density	Medium density D	Low density	Medium density D	Low density	Medium density D	
Phenolic glue	Optimum assembly time	2075	1799	1897	1531	1750	1760	1886	1682	A
		1861	1431	1779	1850	1502	1998	1923	1922	B
		3936	3230	3676	3381	3252	3758	3809	3604	Sum
	Extended assembly time	2107	1549	1554	1737	1665	1888	1470	1844	A
		1808	1677	1912	1967	1686	1526	1803	1709	B
	A	3915	3226	3466	3704	3351	3414	3273	3553	Sum
Urea glue G	Optimum assembly time	1474	1771	1903	1768	1855	1905	1550	1488	A
		2083	1961	1606	2072	1431	1532	1815	1706	B
		3557	3732	3509	3840	3286	3437	3365	3194	Sum
	Extended assembly time	1580	1497	1924	1494	1567	1473	1413	1387	A
		1663	1484	2654	1658	1872	2037	1651	1865	B
	A	3243	2981	4578	3152	3439	3510	3064	3252	Sum

Values represent totals of eight cleavage specimens in pounds per inch.
Total of A and B = 111,687

Gross sum of squares	198,121,369
− Correction term	194,906,030
Net sum of squares	3,215,339

Table 6.—DELAMINATION TEST RESULTS

		Douglas-fir core				Mahogany core C				
		Sliced face		Rotary face F		Sliced face		Rotary face F		
		Low density	Medium density D	Low density	Medium density D	Low density	Medium density D	Low density	Medium density D	
Phenolic glue	Optimum assembly time	34.10	34.06	15.04	14.76	18.74	11.08	45.66	10.22	A
		24.13	25.29	12.77	13.06	13.92	24.47	7.10	5.40	B
		58.23	59.35	27.81	27.82	32.66	35.55	52.76	15.62	Sum
	Extended assembly time	28.96	60.75	33.77	38.10	31.29	10.25	50.93	24.16	A
		15.32	25.56	5.11	11.92	26.14	43.12	9.37	12.50	B
	A	44.28	86.31	38.88	50.02	57.43	53.37	60.30	36.66	Sum
Urea glue G	Optimum assembly time	4.25	3.69	9.08	5.68	3.11	1.12	12.49	24.72	A
		1.40	4.25	6.34	3.39	1.40	2.84	6.25	5.11	B
		5.65	7.94	15.42	9.07	4.51	3.96	18.74	29.83	Sum
	Extended assembly time	15.04	13.50	19.31	43.39	10.80	11.37	34.18	17.32	A
		4.25	5.94	9.64	22.15	8.80	4.81	6.26	38.51	B
	A	19.29	19.44	28.95	65.54	19.60	16.18	40.44	55.83	Sum

Values represent delamination percentage totals of four specimens.
Total of A and B = 1097.44

Gross sum of squares	30,792.82
− Correction term	18,818.35
Net sum of squares	11,974.47

Table 7.—WOOD FAILURE TEST RESULTS

		Douglas-fir core				Mahogany core C				
		Sliced face		Rotary face F		Sliced face		Rotary face F		
		Low density	Medium density D	Low density	Medium density D	Low density	Medium density D	Low density	Medium density D	
Phenolic glue	Optimum assembly time	650	470	750	650	680	515	645	690	A
		715	670	680	755	595	430	490	595	B
		1365	1140	1430	1405	1275	945	1135	1285	Sum
	Extended assembly time	535	240	706	710	460	485	420	415	A
		730	505	660	735	385	215	530	570	B
	A	1265	745	1360	1445	845	700	950	985	Sum
Urea glue G	Optimum assembly time	775	790	705	740	520	520	640	735	A
		715	745	785	785	790	790	755	695	B
		1490	1535	1490	1525	1310	1310	1395	1430	Sum
	Extended assembly time	465	345	710	585	565	625	395	410	A
		600	565	770	750	475	230	770	235	B
	A	1065	910	1480	1335	1040	855	1165	645	Sum

Values represent totals of wood failure percentage for eight specimens.
Total of A and B = 38255

Gross sum of squares	24,407,875
− Correction term	22,866,320
Net sum of squares	1,541,555

Conclusions of Each Test

Wood-Failure Test: The wood-failure test for evaluation of interior Philippine mahogany plywood in this experiment was sensitive to all the five main effects inherent in the experiment.

The average wood failure per panel with Douglas-fir core was approximately 82 per cent, and the Philippine mahogany core gave a wood failure of 67 per cent when all the other factors were averaged out. The structural difference between a hardwood and a softwood is the reason for the difference in wood-failure values.

An interesting point should be mentioned here: the core veneers were approximately the same specific gravity, 0.51 for the Douglas-fir and 0.59 for the Philippine mahogany on an oven-dry volume basis. In the hardwood plywood standard (2), it is the accepted practice to allow a lower wood failure for the higher density species used in the plywood. However, mahogany is not generally considered as a high-density species.

The sliced-mahogany face yielded a lower percentage of wood failure than the rotary face when all the other factors were averaged out. Because the fibers in the sliced veneer intercept the surface at an angle because of the interlocked grain in mahogany, a lower amount of wood failure resulted in the sliced veneer construction when the specimens failed in shear.

The method of manufacture also contributes to the lower wood failure of the sliced veneer in the shear test. Rotary-cut veneer contains lathe checks that will be pulled open, which results in a much greater wood failure than in the sliced veneer, which does not contain lathe checks. This effect was not pronounced in this experiment, as would have been the case if all the specimens had been pulled open.

The low-density face with each veneer type showed the higher percentage of wood failure compared to the medium-density veneer when all the other factors were averaged out. Since density is considered to be an indication of strength, the lower density would offer the least resistance to shear and yield correspondingly more wood failure. The failure is more apt to occur in the low-density face than at the glue line or core, provided the glue line is stronger.

The urea glue yielded a higher percentage of wood failure than did the phenolic glue when all the other factors were averaged out. This result is due in part to a poorer glue mix of

Table 8.—ANALYSIS OF VARIANCE SUMMARY MASTER TABLE

	Shear strength test		Northcott's cleavage test		Delamination machine test		Wood failure	
	Ratio	Sign.	Ratio	Sign.	Ratio	Sign.	Ratio	Sign.
Cores C	1.49	N.S.	2.13	N.S.	†	N.S.	14.57	***
Faces F	†	N.S.	†	N.S.	†	N.S.	7.50	**
Density D	1.90	N.S.	1.61	N.S.	†	N.S.	3.67	*
Glues G	2.37	N.S.	†	N.S.	13.42	***	3.07	*
Assembly A	2.73	N.S.	†	N.S.	6.12	**	23.08	***
(Times) CF	†	N.S.	1.07	N.S.	1.76	N.S.	1.65	N.S.
CD	†	N.S.	4.00	*	1.83	N.S.	†	N.S.
CG	†	N.S.	†	N.S.	†	N.S.	†	N.S.
CA	3.87	*	†	N.S.	†	N.S.	†	N.S.
FD	†	N.S.	†	N.S.	†	N.S.	†	N.S.
FG	†	N.S.	†	N.S.	5.98	**	†	N.S.
FA	†	N.S.	†	N.S.	†	N.S.	1.56	N.S.
DG	†	N.S.	†	N.S.	†	N.S.	†	N.S.
GA	†	N.S.	†	N.S.	†	N.S.	1.80	N.S.
DA	†	N.S.	†	N.S.	1.24	N.S.	1.61	N.S.
CFD	†	N.S.	†	N.S.	†	N.S.	†	N.S.
CFG	†	N.S.	2.73	N.S.	†	N.S.	†	N.S.
FDG	†	N.S.	1.37	N.S.	2.46	N.S.	3.29	*
DGA	†	N.S.	2.04	N.S.	†	N.S.	1.07	N.S.
FDA	†	N.S.	†	N.S.	†	N.S.	†	N.S.
CFA	†	N.S.	1.85	N.S.	†	N.S.	2.11	N.S.
CDG	†	N.S.	†	N.S.	†	N.S.	†	N.S.
CGA	2.88	N.S.	†	N.S.	†	N.S.	†	N.S.
FGA	†	N.S.	†	N.S.	†	N.S.	†	N.S.
CDA	1.18	N.S.	1.15	N.S.	†	N.S.	†	N.S.
CFDG	†	N.S.	2.25	N.S.	†	N.S.	†	N.S.
FDGA	†	N.S.	1.75	N.S.	†	N.S.	†	N.S.
CDGA	1.84	N.S.	2.87	N.S.	†	N.S.	†	N.S.
CFGA	1.18	N.S.	†	N.S.	†	N.S.	†	N.S.
CFDA	1.55	N.S.	1.52	N.S.	†	N.S.	1.27	N.S.
CFDGA	1.33	N.S.	†	N.S.	†	N.S.	†	N.S.
Blocks	4.24	**	3.31	*	6.90	**	1.46	N.S.

†is used when the variance ratio is less than one;
*is used to denote a significance of 90% probability;
**is used to denote a significance of 95% probability;
***is used to denote a significance of 99% probability.

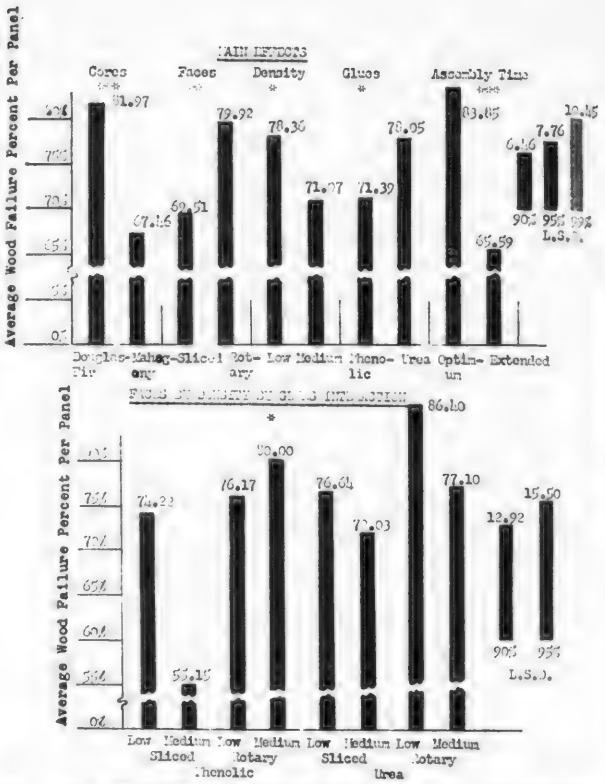

Fig. 9.—Wood failure test—significant main effects and interaction in graph form.

the phenolic glue. Characteristics of the particular urea glue mix used in the experiment could also be more favorable to gluing Philippine mahogany.

Optimum assembly time, of course, gave the greatest amount of wood failure compared to the extended assembly time when all the other factors were averaged out. The better glue bond should yield the highest wood failure when the specimens fail in shear. The wood-failure conclusions are somewhat tempered by the second-order interaction of faces by density of face by glues.

Delamination Test: The delamination test was sensitive to two of the five main effects inherent in the experiment.

The urea glue yielded the lowest amount of delamination compared to the phenolic glue when all the other factors were averaged out. The greater delamination in the phenolic glue was due in part to a poorer glue mix, at least for this type of gluing.

Optimum assembly time in the delamination test yielded less delamination than the extended assembly time, as was expected, when all the other factors were averaged out. This shows the sensitivity of the test, since the extended assembly time was only five minutes beyond the maximum recommended for each glue. The test does pick out this rather small extension that produces poor glue bonds.

An important interaction in the delamination test of the face effect and the glue effect showed the sliced veneer combining with the phenolic glue to give the highest delamination. The rapid conduction of the phenolic glue from the glue line in the pores of the sliced face stock accounted for this interaction. The urea glue did not have the high flow property of the phenolic glue.

Strength Tests: The two strength tests in this experiment were not sensitive to the five main effects inherent in the experiment. Each test presented a significant first-order interaction, but the importance that can be placed on the one interaction for each test is rather small.

Block Effect: The block effect showed up significant statistically in three of the four tests. Because of this, the block effect can be attributed to the test panels and not to the test methods. An exact explanation for this effect does not seem to be available. However, possible explanations for the block effect could be the learning process of the author in pressing the panels, glue mix variation, press temperature variation, and room temperature variations that affected the glue bonds despite the checks employed.

By the recognition of the block effect and the testing of its significance, the experimental error was reduced and the sensitivity of the tests was somewhat improved. If the block effect had been included in the experimental error of the experiment, the main effects would not have been reduced in significance. The result of the block effect is that it was present but did not materially affect the conclusions of the experiment.

Summary

1. This paper centers around the development of a delamination machine for faster test results when using the delamination test to evaluate plywood glue bonds. The delamination machine controls the drying air temperature, water temperature, and, automatically, the time of cycle. These controls make the machine an effective quality-control tool for precision testing of plywood.

2. The comparison of the delamination machine to other delamination tests for the evaluation of Douglas-fir plywood was the first step to evaluate the performance of the machine. Essentially the same results of glue-bond quality were obtained by means of the delamination machine and the standard cold-soak test, "S" test, and modified "S" test. With the establishment of the same test results, the value of the delamination machine is apparent for faster and easier test results.

3. It was found that one day of testing in the delamination machine was adequate to determine the quality of glue bonds. A 2 hour soak at 65° F. followed by drying at 145° F. for

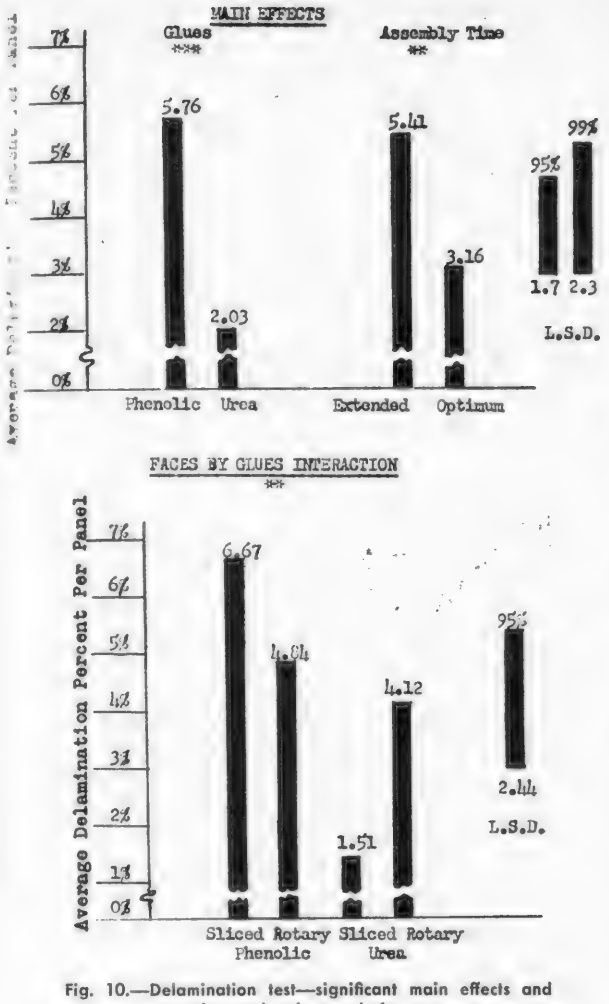

Fig. 10.—Delamination test—significant main effects and interaction in graph form.

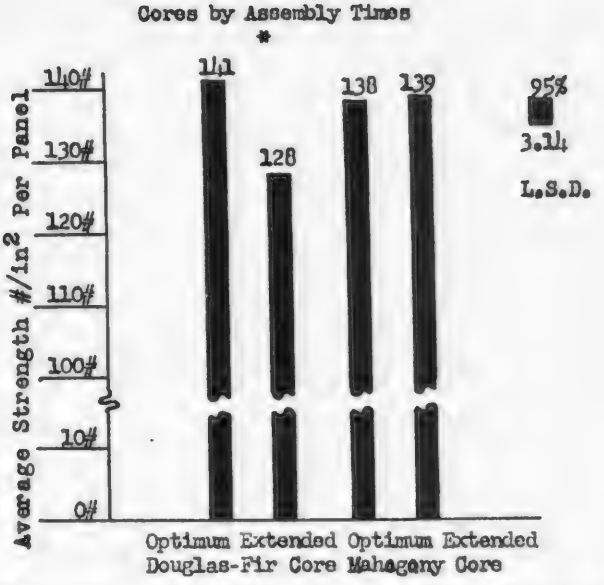

Fig. 11.—Tension-shear test—significant interaction in graph form.

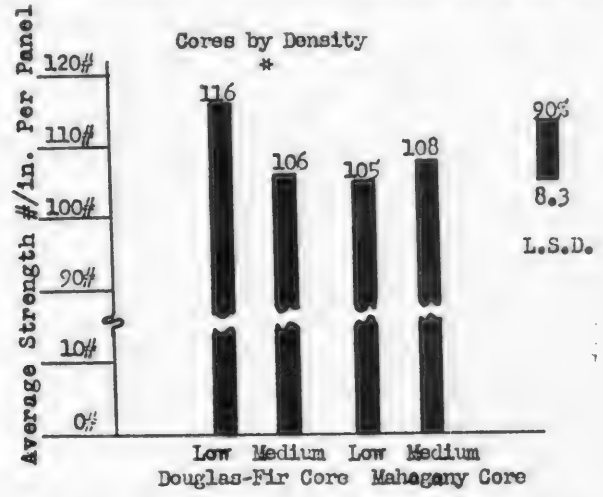

Fig. 12.—Northcott's Cleavage Test—significant interaction in graph form.

four hours was chosen as the optimum cycle because of the more consistent results compared to the other delamination cycles studied.

4. Favorable comparison of the delamination machine to other test methods of evaluating glue lines of Philippine mahogany plywood made in the Puget Sound area of Washington is the final contribution of this paper. The wood-failure test was sensitive to all five main effects of the experiment: core species, mahogany face type, density of face, assembly time, and glue. The wood-failure readings reflect the differences in core species, face type, and density of face, none of which al directly with glue-bond quality.

The delamination cycle of the machine possessed a specific sensitivity to the assembly time and glue effects of the experiment. Strength tests did not show sensitivity to the main effects of the experiment, and thus seem to be limited for evaluating glue bonds.

The wood-failure reading might be the result of the difference in the density of the face rather than the quality of the glue bond. This greater sensitivity of the wood-failure test as compared to the delamination test is the disadvantage of the wood-failure test. The delamination test sems to be the test that is concerned directly with the quality of glue bond and is not sensitive to physical factors of the veneer in the plywood, at least within the limits of the experiment.

Discussion

The conclusions of the study are basically important to the plywood industry as a whole, not just to the producers of Philippine mahogany-faced plywood with Douglas-fir core made in the Puget Sound area of Washington. The automatic delamination test method is a great time-saver and makes the delamination test practical as a quality-control tool for the plywood industry. It is now possible to obtain the test results on panels with poor glue bonds in one day of testing. The machine delamination test method is an easy and fast method that is not inhibited by the eight-hour working day or weekend delays.

The wood-failure method of evaluating interior glue bonds in this study was sensitive to all the five main effects, while the machine delamination test was sensitive only to the glue effect and the assembly time effect. This specific sensitivity to the particular effects that deal directly with poor glue bonds is the advantage of the machine delamination test method.

The factor of density, which this experiment shows to be important to

the wood-failure reading, is almost impossible to control on a quality-control testing program that is evaluated by estimating wood failure. Whether a panel passes or is rejected by the wood-failure test could be a reflection of the density of the veneers in the plywood and not the glue bond quality.

The machine delamination test method is applicable to different combinations of species of cores and face veneers within the limitations of the experiment. The wood-failure method is restricted to setting up a standard set of wood-failure specimens that are correlated to service conditions for each construction.

The skill necessary to read delamination is much less than is required to read wood failure, and this makes for more consistent results between readers of delamination. The delamination test is definitely related to service conditions directly, since the service conditions are basically wetting and drying of the plywood panel.

The machine delamination test method is a practical tool that has application to quality control and research now that the time element is reduced by the use of the delamination machine.

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High Drying Temperatures—Do They Harm Douglas-Fir Veneer?[1]

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Plywood from veneer dried above 400° F. had lower than control breaking strength, after a 2-cycle boil test. Wood failure, however, was not a reliable indication of glue-bond durability. Veneer dried in oil-fired driers produced the least durable glue bonds. Even well-bonded exterior plywood from high-temperature-dried veneers may be of sub-standard strength.

DIRECT-FIRED VENEER DRYERS have become widespread in the Douglas-fir plywood producing region since the first unit was installed in December, 1953. In December 1956, there were 24 direct-fired dryers in Oregon, Washington, and California. About half the dryers burned oil; the remainder burned gas, either natural or propane.

Direct-fired veneer dryers have a decided economic advantage in initial installation and operating costs when compared to conventional steam-heated dryers. For this reason, their initial use was centered in small plywood plants that produced cold-pressed plywood. It is common practice to operate direct-fired dryers at temperatures up to 170° F. higher than those of steam dryers, thereby permitting plants to maintain production with short drying schedules.

In a steam dryer, radiation and convection from steam coils supply heat for drying green veneer; direct-fired dryers circulate products of combustion from burning oil or gas through the veneer dryer. To run efficiently and economically, the operating temperature of short, direct-fired dryers usually must be higher than for steam dryers. Temperatures of 400 to 550° F. are common in direct-fired veneer dryers, as compared with 320 to 380° F. for steam dryers.

One outstanding condition noted in green Douglas-fir veneer dried by direct-fired dryers, rather than in steam dryers, was a difference in color. Veneer in many instances darkened in drying and had a toasted appearance. This color change, however, did not appear to affect the glue bond with typical cold-press glues. Standard quality-control tests for cold-pressed plywood were met without particular difficulty.

In late 1955, the first hot-press operation was started at a plywood plant that prepared veneer by direct-fired drying. Another plant with a direct-fired dryer began to sell part of

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their dried veneer to a firm making hot-pressed exterior plywood. It was soon apparent that veneer from direct-fired dryers frequently produced unacceptable glue bonds with exterior-type phenolic resins.

For the past year, many organizations have been attempting to find causes for poor gluability of veneer from direct-fired dryers when bonded with exterior phenolic resin glues. Work has been done by leading glue companies, by dryer manufacturers, and by the Douglas Fir Plywood Association. The U. S. Forest Products Laboratory is considering the problem.

Similar bonding problems have been encountered previously. During World War II, difficulty was encountered in secondary gluing of aircraft plywood. Sanding plywood surfaces prior to gluing increased joint strength by removing surface glaze from hot pressing, glue bleed-through, and wax deposits (2, 7).[2] Wood surfaces free from contaminating substances are essential for good gluing (5).

Background

The theory of reduction of hygroscopic properties in wood heated at high temperatures also was given attention at an early date (2, 16). Recently, evidence was presented to modify early thoughts about hygroscopicity (14). Although the exact pattern of chemical changes has not been explained, it is known that wood subjected to high drying temperatures loses part of its ability to absorb water (6, 9, 14, 16).

It seems logical to assume that surface wetting action of a wet glue mix on veneer dried at high temperatures could be affected by decrease in wood hygroscopicity. Good wetting of the bonding surfaces by glue is a basic requirement for a satisfactory glue joint (4, 5, 18). In studies where drying temperature of veneer was a variable, it has been reported that low drying temperatures produced plywood with superior glue bonds (1, 3, 12, 15, 18).

Another critical factor to consider in high-temperature drying is loss of wood strength. Published reports have shown that toughness and work to maximum load are strength properties of Douglas-fir most affected by heating at high temperatures. Modulus of rupture, modulus of elasticity, and fiber stress at proportional limit also are reduced (8, 9, 17). A significant reduction in breaking load of plywood shear specimens made from high-temperature-dried veneers has been reported (10). Work is in progress at the Douglas Fir Plywood Association to determine loss in bending strength

[2] Numbers in parentheses refer to literature cited.

Fig. 1.—Soot on white tissue was wiped from veneer dried in oil-fired dryer 3.

of Douglas-fir veneer when dried at high temperatures. Plywood made from veneer so dried also will undergo strength tests.

Additional factors may complicate the problem of producing satisfactory hot-pressed plywood from direct-fire-dried veneers. For example, veneers from such dryers often have uneven distribution of moisture (1, 6, 15). Uneven drying is caused in part by extreme variations in temperature often encountered in direct-fired dryers. One study showed a range of 290° to 500° F. across the width of a dryer set to operate at 410° F. (1).

Another characteristic of Douglas-fir veneer that affects glue-line quality is "hard-grain" veneer from some areas of the Douglas-fir region (3, 13, 18). This veneer is difficult to glue after any type of drying, but it has been reported that low temperatures in drying produce better plywood from hard-grain veneer than do high temperatures (3).

Exploratory work on gluability of Douglas-fir veneers dried at high temperatures was initiated at the Forest Products Research Center in December, 1955. Available data concerning the problem were collected, including information from operators of plywood plants with direct-fired dryers. A short study was conducted to obtain rates of water absorption for veneer oven-dried at temperatures ranging from 220° to 550° F. Results showed that water absorption was reduced by increased drying temperatures and also by lengthened drying times at given temperatures. Dipping dried veneer in solutions of chemicals such as caustic soda or solvents such as alcohol improved the water-absorbing capacity. In March 1956, a preliminary report on the exploratory work was distributed to plywood plants and to other research organizations (6).

The problem of producing high-quality exterior plywood from veneers dried at high temperatures grew more important as each additional direct-fired dryer was placed in service. Although many organizations were attacking the problem, a solution had not been found. Because of these circumstances, a full-scale research project was initiated by the Forest Products Research Center. Objectives of the project were to investigate factors leading to poor bonding in hot-pressed plywood made from veneers dried at high temperatures and to attempt to overcome the gluing difficulty.

Since the problem was new to the plywood industry, and involved many factors that could contribute to poor bonding, a complete plan of attack could not be outlined in advance. Instead, results had to be obtained from experimental plywood and analyzed to guide procedure for further research.

What Was Done

Many important variables in plywood manufacture contribute to final quality of the glue bond. In the present study, the primary factor under consideration was effect of veneer drying conditions on bond quality. It was desirable, therefore, to standardize all other factors that could be controlled. In all experimental plywood pressed during the investigation, the following factors were held constant:

- Veneer—1/10-inch Douglas-fir heartwood.
- Plywood panel size—1-foot square.
- Glue—D.F.P.A. approved, extended hot-press phenolic resin.
- Glue spread— 55 lbs/M sq ft of double glue line.
- Plywood construction—5-ply, ½-inch.
- Closed assembly time—10 minutes.
- Pressing temperature—285° F.
- Pressing pressure—200 psi.
- Pressing time—6 minutes.
- Panels per opening—1.
- Residual curing—stacked for 3 hours at 180° F.

Three groups of plywood panels were studied. The first group consisted of panels assembled from veneer dried by various means, including dryer types common on the West Coast. In the second group of test panels, verification was sought for results from the first group, and, in addition, some panels were assembled from redried veneer to assess the effect of extended drying time. The third group of test panels was made only of veneer from oil-fired dryers, with

Fig. 2.—Wire-brushing surface deposits on veneer dried on an oil-fired dryer.

half being wire-brushed to gauge the effect of such surface treatment. Veneer for each plywood group came from a different Oregon plant.

Veneer gluability was assessed by three different methods:

- Wood-failure tests by the Douglas Fir Plywood Association
- Water-absorption tests on the dried veneer
- Delamination-resistance tests designed to rate glue-line durability in repeated dry-boil cycling.

In the past few years, the question of correlation between percentage of wood failure, as measured by the D.F.P.A. 2-cycle boil test for exterior type plywood, and actual field performance of plywood has received renewed attention.

In the wood failure test of the Douglas Fir Plywood Association, specimens of exterior plywood are boiled 4 hours, dried 16 hours at 145° ± 5° F., boiled 4 hours, and tested wet in a standard shear testing machine for plywood. Percentage of wood failure is estimated after broken pieces dry.

Use of wood failure by the D.F.P.A., rather than breaking strength, as a basis for predicting exterior plywood durability is well documented by N. S. Perkins (11). Thousands of tests performed on specimens subjected to outdoor exposure have shown that durable bonds can be correlated with high wood failure. Some test panels have been exposed for about 15 years.

Specimens on an outdoor test fence are exposed to alternate wetting and drying from natural changes in the weather. Fluctuations in moisture content of plywood result in constantly changing stresses on glue lines as the wood alternately shrinks and swells. Inferior glue lines that cannot withstand these stresses will delaminate.

With this relationship in mind, a new test procedure was developed to test delamination resistance of representative specimens from plywood made in groups one, two, and three. Eighteen standard shear specimens were prepared from each 1-foot-square plywood panel; five at random were given the standard D.F.P.A. test. From the remaining 13 specimens, four were chosen at random for the special test. Since there were five panels pressed for each drying method, this selection gave a total of 20 specimens per treatment for the delamination resistance test and 25 per treatment for the D.F.P.A. test.

Test procedure consisted of drying the specimens for 20 hours at 145° ± 5° F., followed by boiling in water for 4 hours. While still hot and wet, one end of the specimen was clamped with a small air cylinder, and a 5-pound weight was suspended momentarily from the extreme end of the unclamped portion (Fig. 3). This cycle was repeated 25 times. In each cycle, the uppermost notch in the specimen always was positioned close to the air cylinder, but no effort was made to insert the same end of the specimen under the clamp. This procedure resulted in random application of stresses on the two core-crossband glue lines. Preliminary tests showed that a 5-pound weight would supply force to delaminate poor glue lines, but seldom would cause a break across the uppermost notched area of the specimen.

Glue-Line Tests

Plywood Group One: Green A-grade veneer was obtained for plywood group one directly behind the clipper in a plywood plant. Similar veneer in 2- by 10-foot sheets was chosen, and to facilitate handling, each piece was clipped to make two 2- by 5-foot sheets.

The veneer sheets, chosen at random, were sorted into 5 subgroups of 3 sheets each. Each subgroup was dried by 1 of 5 different drying methods:

- Steam dryer—6.9 minutes with 320° F. in the green end, 350° F. in the center section, and 345° F. in the dry end.
- Gas-fired dryer—9 minutes with 360° F. in the green end, 390° F. in the center section, and 380 F. in the dry end.
- Oil-fired dryer—4 minutes with 475° F. in the green end (only temperature measurement available).
- Dry kiln—veneer cut into 1-foot squares. Dried for 21 hours at 150° F. with equilibrium moisture content conditions set at 2.9 per cent.
- Electric oven—veneer cut into 1-foot squares. Dried for 10 minutes at 430°–450° F.

Fig. 3.—In the special 25-cycle delamination tests, an air-operated clamp held one end of a plywood shear specimen while a 5-pound weight was suspended from the free end.

Temperatures in the commercial veneer dryers were taken from thermometers located on sides of the dryers. Oven drying was done in an electrically heated oven modified to dry veneer at high temperatures; thermocouples placed in the entering and leaving air streams of the oven allowed close check of air temperatures.

Plywood Group Two: Veneer drying conditions for plywood group two were chosen to verify results found in plywood group one. No veneer was steam-dried, as it was believed that kiln-dried veneer would provide sufficient comparison with veneer dried at high temperatues. The primary aim was to determine if oil-dried veneer consistently showed poor glue bonds. Another factor under consideration was the effect of additional exposure to high drying temperatures on veneer strength and gluability. Many direct-fired veneer dryers, especially the short ones, produce veneer that is dried unevenly. When uneven drying occurs, the veneer usually is rerun through the dryer. In any dryer, heartwood veneer with included sapwood dried on a heart schedule often is pulled for redrying.

Green, A-grade veneer in similar 2- by 8-foot sheets for group two panels was obtained. Each 2- by 8-foot sheet was clipped to make four 2-foot-square pieces that were sorted into 4 separate subgroups. Each of the 4 subgroups was dried by one of the following conditions:

- Gas-fired dryer—the dryer schedule was 5.5 minutes at 380°–425° F. Half the veneer was put through the dryer once, and the other half twice.
- Oil-fired dryer—the dryer schedule was 5 minutes at 400°–

460° F. Half the veneer was put through the dryer once, and the other half twice.

- Dry kiln—veneer was cut into 1-foot squares and dried for 21 hours at 150° F. with EMC conditions set at 2.9 per cent.
- Electric oven—veneer was cut into 1-foot squares and dried for 10 minutes at 490°–525° F.

Plywood Group Three: Results for groups one and two indicated that the oil-dried veneer gave inferior bonds; thus, this method of drying required further investigation.

Sheets of 2- by 8-foot green veneer were chosen at random for plywood group three and were sorted into 3 subgroups of 15 sheets each. Each of the 3 subgroups was dried in 1 of 3 different oil-fired dryers under the following conditions:

- Oil-fired dryer 1(6 drying sections)—3 minutes at 490°–520° F.
- Oil-fired dryer 2 (8 drying sections)—4.25 minutes at 530° F.
- Oil-fired dryer 3 (8 drying sections)—6 minutes at 380° F.

All temperatures were read from indicating recorders that controlled the temperature of combustion gases in the reheating ducts, because recorders were the only means available for measuring internal temperatures in two of the oil-fired dryers. It has been stated that temperatures measured in reheating ducts of direct-fired dryers can be up to 75° F. higher than those indicated by thermometers located along the sides (1).

The temperature in dryer 3 had been cut from 500° to 380° F. because of customers' complaints that the veneer was scorched. Lowering the temperature led to another problem, because the veneer then became covered with heavy, oily soot.

Extent of these surface deposits on veneer from oil-fired dryer 3 is shown in Fig. 1. Dryers 1 and 2 also produced veneer with soot deposits, but such deposits were found primarily where two veneers had overlapped in drying. Exposed surfaces of overlapped areas had heavy concentrations of oil deposits.

Plywood group three was studied to determine the relative gluability of oil-dried veneers that had been wire-brushed. Five of the fifteen 2- by 8-foot veneer sheets dried in a particular oil-fired dryer were cut into 1-foot squares. Ten 5-ply plywood lay-ups were assembled with veneer from sheet 1 for face plies, sheet 2 for crossbanding, sheet 3 for cores, sheet 4 for crossbanding, and sheet 5 for backs. All veneers in 5 of the 10 lay-ups were brushed on both sides with a portable rotary wire brush (Fig. 2). The actual loss in veneer thickness from wire brushing averaged 0.002 inch. Brushing removed soot and most darkened surface fibers from soft springwood areas on the veneer surface. Some soot on dense summerwood was still visible after wire brushing, especially in those areas where overlaps occurred in drying the veneer. Care was exercised to make certain that orientation of tight and loose sides of the veneer was identical in both brushed and unbrushed veneer.

Water Absorption Tests on Dried Veneer

Exploratory work showed that elevated drying temperatures at a given length of time, or increased drying time at the same temperature, resulted in decrease in water-absorbing capacity of Douglas-fir veneer (6). To verify this conclusion, water absorption of group one veneer was determined for several different drying conditions.

Veneer remaining after making panels for plywood group two also was tested for water absorbency. The only drying condition differing from those used in making plywood was the oven drying. Plywood in group two was made from veneer oven-dried at 490°–525° F. for 10 minutes, while veneer to be tested for water absorbency was oven-dried at 460° F. in 2 passes of 5 minutes each. Theoretically, 2 passes at 460° F. was similar to time-temperature conditions encountered by veneer redried in the oil-fired dryer.

Results and Discussion

Glue-Line Tests

Plywood Group One: Each method of veneer drying in group one (veneer dried by 1 of 5 different means) yielded plywood that passed the D.F.P.A. minimum rating of 85 per cent wood failure, except for veneer dried in an oil-fired dryer; this plywood averaged only 59 per cent wood failure (Table 1). Many broken test specimens in the oil-dried subgroup showed complete lack of wood failure as it normally appears. Fine fibrous fuzz, however, was prevalent over scattered areas.

Although oven-dried veneer rated 90 per cent wood failure, the type of fracture was not normal, as many breaks were brashy. Breaking loads for oven-dried veneer were much lower than for steam-, gas-, or kiln-dried veneer. Since oven-dried veneer was subjected to high drying temperatures (430° to 450° F.), support was given to the theory that high temperatures adversely affect wood strength. Loss in breaking load was greatest in the oil-dried subgroup, which was also dried at high temperature (475° F.). It was not clear, however, whether the loss was caused by inferior glue bonds (as indicated by low wood failure), by actual deterioration of wood strength, or by a combination of both factors.

Delamination resistance of plywood from the five different veneer-drying methods making up plywood group one showed a wide range. Oil-dried veneer delaminated completely in 15

Table 1.—BREAKING LOADS, PERCENTAGE OF WOOD FAILURE, AND DELAMINATION RESISTANCE OF 5-PLY, ½-INCH PLYWOOD CONSTRUCTED WITH 1/10-INCH DOUGLAS-FIR HEARTWOOD VENEERS DRIED BY SEVERAL METHODS

	Dryer type, and conditions	Standard D.F.P.A. exterior test		Specimens intact at the end of dry-boil cycle number								
		Breaking load Psi	Wood failure %	1 %	2 %	3 %	4 %	5 %	10 %	15 %	20 %	25 %
One	Steam dryer; 6.9 min. @ 320–350°F.	215	88.8	100	100	100	100	100	100	100	100	90
	Dry kiln; 21 hours @ 150°F.	192	92.4	100	100	100	100	100	100	100	95	95
	Gas-fired; 9 min. @ 360–390°F.	202	90.6	100	100	100	100	100	95	80	50	45
	Oil-fired; 4min. @ 475°F.	138	58.8	100	100	100	100	95	30	0	---	---
	Electric oven; 10 min. @ 430–450°F.	167	90.0	100	100	100	100	100	95	95	90	55
Two	Dry kiln; 21 hours @ 150°F.	258	90.4	100	100	100	100	100	100	100	100	100
	Gas-fired; 5.5 min. @ 380–425°F.	141	83.8	100	100	100	100	100	100	100	95	95
	Gas-fired, redried; 11 min. @ 380–425°F.	191	54.6	100	100	100	100	100	100	90	70	55
	Oil-fired; 5min. @ 440–460°F.	162	22.6	100	95	85	80	50	10	5	0	---
	Oil-fired, redried; 10 min. @ 440–460°F.	113	71.2	95	85	80	60	40	0	---	---	
	Electric oven; 10 min. @ 490–525°F.	144	83.8	100	100	100	100	93	77	33	0	---
Three	Oil-fired: 1; 3 min. @ 490–520°F.*	198	43.4	100	100	75	65	45	10	5	0	---
	1; wire-brushed	220	60.2	100	100	100	100	100	85	50	15	5
	2; 4.25 min. @ 530°F.*	173	94.2	100	100	100	90	75	5	0	---	---
	2; wire-brushed	197	75.2	100	100	100	100	100	95	60	30	10
	3; 6 min. @ 380°F.*	103	0.8	50	35	10	5	0	---	---	---	---
	3; wire-brushed	177	62.2	100	100	100	100	100	70	25	5	0

*Burner controller temperature. All others read from thermometers.

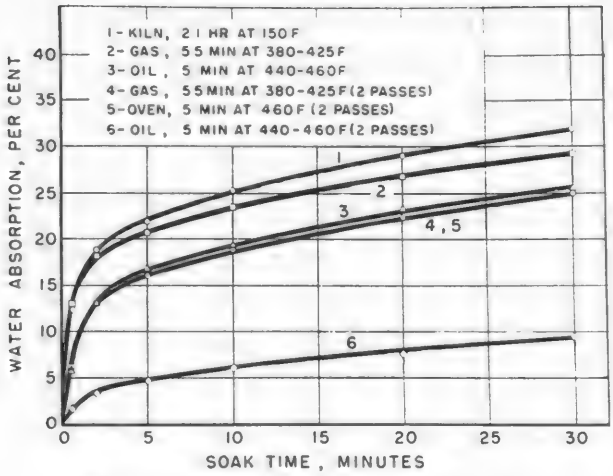
1-KILN, 21 HR AT 150F
2-GAS, 55 MIN AT 380-425F
3-OIL, 5 MIN AT 440-460F
4-GAS, 55 MIN AT 380-425F (2 PASSES)
5-OVEN, 5 MIN AT 460F (2 PASSES)
6-OIL, 5 MIN AT 440-460F (2 PASSES)
WATER ABSORPTION, PER CENT
SOAK TIME, MINUTES

Fig. 4.—Average water absorption of veneer used in plywood group two.

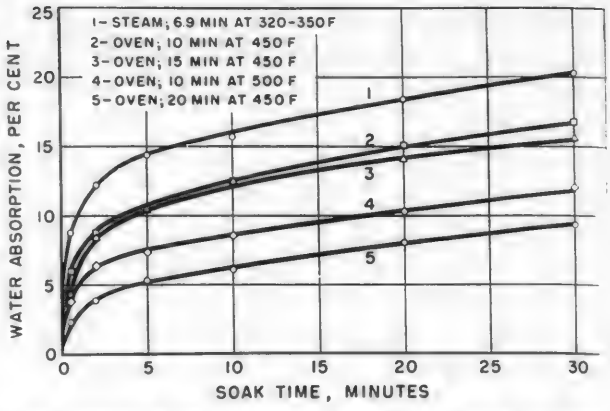
1-STEAM; 6.9 MIN AT 320-350F
2-OVEN; 10 MIN AT 450F
3-OVEN; 15 MIN AT 450F
4-OVEN; 10 MIN AT 500F
5-OVEN; 20 MIN AT 450F
WATER ABSORPTION, PER CENT
SOAK TIME, MINUTES

Fig. 5.—Average water absorption of group one veneer dried und several different drying conditions.

cycles. Plywood made from kiln- or steam-dried veneer, however, went through 25 cycles with 90 per cent or more of the specimens intact (Figs. 6, 9). These two methods of drying veneer were the principal ones used during testing by the D.F.P.A. of the hypothesis that high wood failure indicated long exterior durability. Resistance to delamination shown in Fig. 6 for plywood made from kiln- and steam-dried veneer substantiated the D.F.P.A. findings.

There was evidence from group one that veneer dried at high temperatures will not show close correlation between high wood failure and resistance to delamination. Both oven- and gas-dried veneer rated at least 90 per cent wood failure by D.F.P.A. test, but at the end of 25 dry-boil cycles, about half the specimens had delaminated. If the cycles had been stopped at 10 instead of continuing to 25, both oven- and gas-dried veneer would have shown only 5 per cent delamination. Most failures that occurred after the tenth cycle were in the wood and not in the glue line. Strength loss in wood dried at high temperatures may offer a good reason for delamination of oven- and gas-dried types after exposure to several dry-boil cycles.

Plywood Group Two: Plywood made from kiln-dried veneer was the only type in group two (veneer dried by 1 of 4 different means) that exceeded the D.F.P.A. allowable minimum for wood failure (Table 1). Both oven- and gas-dried (one pass) veneer were slightly under the 85 per cent allowable minimum wood failure. When gas-dried veneer was redried, wood failure dropped from 84 to 55 per cent, while breaking load increased from 141 to 191 psi. The reverse was true with the oil-fired dryer; redried veneer gave increased wood failure coupled with decreased breaking load when compared to veneer oil-dried once.

Part of the apparent inconsistency in results noted can be explained by appearance and strength of the breaks. In group two, all methods of drying except kiln-drying can be considered high-temperature, as they were over 400° F. Kiln-dried veneer averaged 258 psi in breaking load. With kil dried veneer as a base, drop in brea ing loads of veneer dried at high ten peratures ranged from 26 per cent f that redried in a gas-fired dryer to per cent for twice-run oil-dried venee

Evidence of brash failures w found in veneer dried in the electr oven and in veneer redried in a oil-fired dryer (Fig. 10). Possibl strength of the wood was reduced t such a degree that failure took pla primarily in the wood and not in th glue line, hence increasing wood fai ure. Veneer put through the oil-fire dryer once gave many glue joints a most completely lacking in wood fail ure, yet the joint strength was greate than with similar veneer that had bee put through the dryer twice. However, reasons for increased breaking load of the two-pass gas-dried veneer were not clarified by this explanation.

It is possible that lathe-check orientation influenced the relationship of shear load to wood-failure percentage. Orientation of direction of lathe checks in the plywood shear specimens was not controlled strictly. Cutting proce-

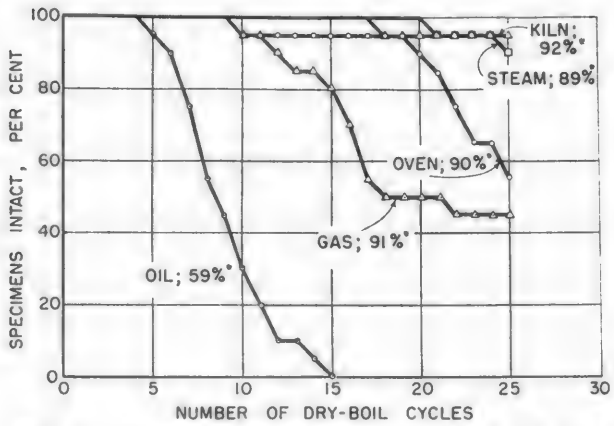

Fig. 6.—Delamination resistance of pulpwood group one, standard shear specimens subjected to 25 dry-boil cycles compared with initial wood failure ratings. (*Wood failure by D.F.P.A. test.)

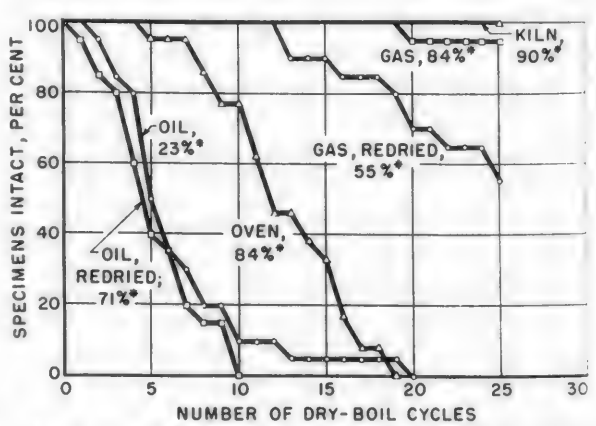

Fig. 7.—Delamination resistance of plywood group two, standc shear specimens subjected to 25 dry-boil cycles compared with initi wood failure ratings. (*Wood failure by D. F. P. A. test.)

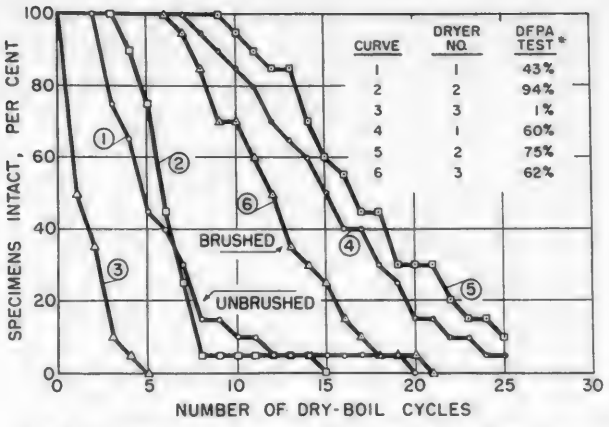

Fig. 8.—Delamination resistance of plywood group three, standard shear specimens, subjected to 25 dry-boil cycles compared with initial wood failure ratings. (*Wood failure by D.F.P.A. test.)

dure in preparing shear specimens should have resulted in random orientation of lathe checks, however.

Results of the special tests of delamination resistance for plywood group two (Fig. 7) emphasized findings made in plywood group one. Veneer kiln-dried at mild temperatures showed no delamination in 25 cycles. Plywood made from veneer dried once in a gas-fired dryer had only 5 per cent delamination, while similar veneer redried in a gas-fired dryer began to delaminate steadily after the twelfth test cycle. Veneer gas-dried once in plywood group one (Fig. 6) showed much greater delamination than that in plywood group two, but, since veneer in the two groups came from different sources, direct comparisons are not possible.

Oven-dried veneer in group two was dried at higher temperatures than was veneer oven-dried in group one (490° to 525 F. compared to 430° to 450° F.), but drying times were identical (10 minutes). In the delamination test, 8 of 20 specimens broke across the notch nearest the clamped end of the specimens when the 5-pound weight was applied. The breaks were brashy (Fig. 10). Since it did not seem reasonable to call such a break glue-line delamination, these 8 specimens were not included when resistance to delamination was plotted (Fig. 7). Even with this type failure excluded, the remaining oven-dried specimens were completely delaminated before cycle 20 was completed.

One of the puzzling relationships found in D.F.P.A. tests on oil-dried veneer from plywood group two was in ratings of wood failure for veneer dried once and twice. Plywood from veneer oil-dried once rated 23 per cent wood failure; that dried twice rated 71 per cent. The 25-cycle delamination tests showed that both types possessed extremely poor bonds, with the one-pass veneer being slightly more resistant to delamination. Practically all delamination breaks occurred in the glue line. In the D.F.P.A. test, two-pass oil-dried veneer failed largely in the wood, but specimens dried once failed in the glue line.

Plywood Group Three: Wire-brushed veneer from two of the three oil-fired dryers for group three (veneer dried in 1 of 3 different oil-fired dryers) gave an increase in wood failure by the D.F.P.A. test when compared to unbrushed veneer from the same dryer (Table 1). For dryers 1 and 3, increases were 17 and 61 per cent, respectively. The most spectacular change was found for veneer from dryer 3, where unbrushed veneer rated 1 per cent wood failure, compared to 62 per cent for similar veneer that was wire-brushed (Fig. 11). This particular dryer, operating at about 150° F. below the temperature of the other dryers, produced veneer covered with surface deposits. The bond in unbrushed veneer from dryer 3 was so poor that some test specimens fell apart in the boil cycle before they could be tested.

Much of the apparent gain in wood failure by wire brushing was not in broken chunks, but in fine surface fibers (Fig. 12). This type failure was evident to a lesser degree in wire-brushed veneer from dryer 2, where brushing decreased average wood failure by 19 per cent when compared to unbrushed, but increased the breaking load in the D.F.P.A. test.

Fig. 9.—Specimens in plywood group one, of kiln-dried veneer, exhibited high wood failure in the D.F.P.A. dry-boil test (left), and most of them survived the special 25-cycle delamination test (right).

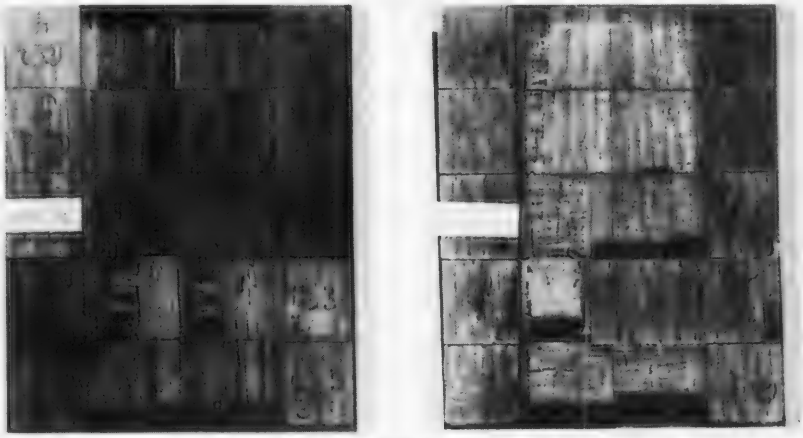

Fig. 10.—In specimens from plywood group two, oven-dried veneer, breaks were brashy in the D.F.P.A., 2-cycle boil test (left), and in the 25-cycle special delamination test (right).

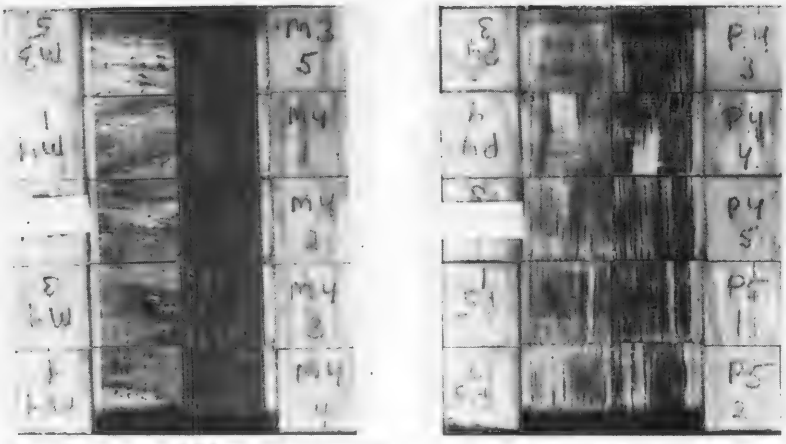

Fig. 11.—In the D.F.P.A. 2-cycle dry-boil test of group three plywood of veneer dried in oil-fired dryer 3, unbrushed veneer (left) had little wood failure, but brushed veneer (right) had considerable wood failure.

Wire-brushed veneer from all three dryers gave increased breaking loads when compared to unbrushed veneer. These increases were 11, 14 and 72 per cent for dryers 1, 2, and 3, respectively. In oil-fired dryer 2, the situation was similar to one found in plywood group two where twice-run gas-dried veneer had decreased wood failure and increased strength when compared to veneer dried once.

Results for the delamination test of plywood group three may be found in Fig. 8. Increased resistance to delamination from wire-brushing oil-dried veneer was quite apparent, but durability was inferior to that of gas-dried veneer in groups one and two. It was interesting to note that delamination relationships among veneers from the three oil-fired dryers were similar in brushed and unbrushed veneer.

Tests of delamination for both brushed and unbrushed veneer from dryers 1 and 3 showed close correlation with D.F.P.A. estimations of wood failure. Results of the delamination cycles in veneer from dryer 2 again were contrary to those found in the D.F.P.A. test, which showed that unbrushed veneer rated 94 per cent wood failure compared to 75 per cent for brushed veneer (Fig. 11). At the end of cycle 10, unbrushed veneer, however, was 90 per cent delaminated compared to 5 per cent delamination in brushed veneer. The delamination test, moreover, showed almost complete lack of wood failure in some of the core-crossband glue lines that rated 100 per cent wood failure in the D.F.P.A. test (Fig. 12).

In plywood from all three dryers, whether brushed or unbrushed, the delamination test cycles uncovered many failures in the face ply-crossband glue lines. This type failure was not evident in the D.F.P.A. tests (Fig. 12).

Presence of heavy, oily soot appeared significant on some veneers from oil-fired dryers for group three plywood.

There is little doubt that oily substances on the surface of wood will interfere with gluing. It has long been recognized that naturally oily woods, such as cypress or teak, will not give satisfactory glue bonds unless the bonding area is surfaced or sanded immediately before gluing. Sanding or planing Douglas-fir veneer to remove surface deposits before gluing probably would be impractical for several reasons. Veneers would have to be cut thicker to allow for loss, and much breakage would occur because of low moisture content of the veneer. Increased costs would be heavy. A more practical and possibly less costly method to remove surface deposits would be brusing with a flexible rotary wire or fiber brush. A unit of this type with an automatic feed could be located at the outfeed end of a veneer dryer.

Factors other than visible surface deposits on oil-dried veneer can contribute to reduced gluability. It has been reported that drying atmospheres containing sulfur dioxide produced veneers more difficult to glue than veneers dried in atmospheres containing air alone, or air plus carbon dioxide (1). In these drying-atmosphere experiments, there was no chance for surface contamination by soot or oil deposits. Since low-grade fuel oil used in oil-fired dryers contains sulfur, the possible effect on veneer gluability is obvious.

Half the unbrushed specimens from veneer dried in dryer 3 fell apart in the first cycle of the 25-cycle special test. Seven dry-boil cycles were required to delaminate the first brushed specimen. This result strongly indicated that surface deposits, such as those found on veneer dried in oil-fired dryer 3, had serious adverse effect on glue bonds made with exterior phenolic resins. Light wire-brushing produced bonds with increased durability, but the increase was not great enough to put brushed oil-dried veneer on a par with steam, kiln, or gas-dried veneer.

Water Absorption Tests on Dried Veneer

Relationship of water absorption to soak time for group one veneer is shown in Fig. 5, where each plotted point represents the average of 10 specimens. Results followed the same pattern found in exploratory work where elevated temperatures or increased drying time lowered the water absorbency of Douglas-fir veneer.

Results of water-absorption tests for group two veneer are given in Fig. Relationships of drying time and temperature to water absorption followed the pattern previously found. There was some loss in water absorbency for veneer redried in the gas-fired dryer compared to veneer dried once. The greatest loss from redrying occurred in the oil-fired dryer. After 30 minutes of soaking, the water absorption of re

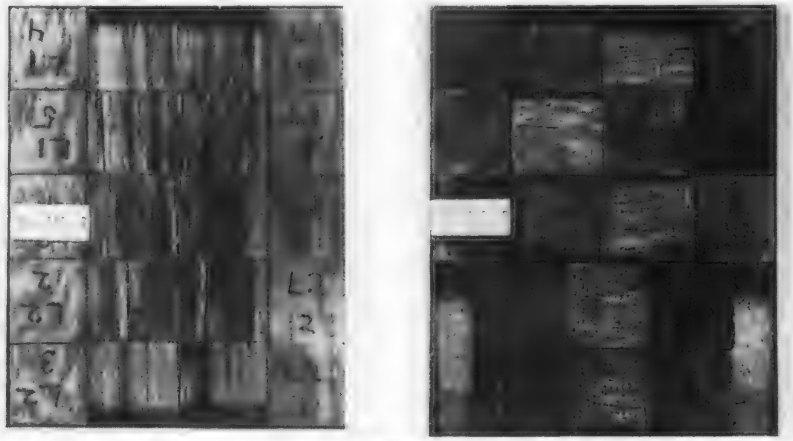

Fig. 12.—Fig. 12.—In plywood group three, of unbrushed veneer from oil-fired dryer 2, high wood failure was found in the 2-cycle dry-boil D.F.P.A. test (left), but specimens delaminated with slight wood failure after several cycles of the special delamination test (right.)

dried veneer was less than 10 per cent, compared to 26 per cent for veneer oven-dried once. Veneer oven-dried by the same schedule as the twice-run, oil-dried veneer was comparable in water absorption to oil-dried veneer that had gone through the dryer only once.

If it is assumed that water absorption of veneer is a reliable indication of veneer wettability by glue, then joints made from veneer oil-dried once should be superior to those from veneer oil-dried twice. Wood failure of oil-dried veneer in plywood group two showed the opposite reaction; veneer oil-dried once rated 23 per cent and veneer oil-dried twice rated 71 per cent wood failure. Breaking strength of plywood from veneer oil-dried once, however, was 43 per cent more than that of plywood from veneer oil-dried twice. Kiln-dried, gas-dried-once and gas-dried-twice veneer showed close correlation between water absorption and percentage of wood failure.

Summary

Conflicting results in attempted correlation of water absorbency of veneer and wood failure by the D.F.P.A. test gave additional indication that a different evaluation procedure was necessary to determine glue-bond integrity of plywood made from veneers dried at high temperatures.

Based on tests conducted on Douglas-fir plywood made from veneers dried by various methods, effects of veneer drying conditions on quality of hot-pressed exterior-type plywood can be summarized as follows:

1. Within the same veneer source, drying temperatures above 400° F. resulted in loss in breaking strength of D.F.P.A. 2-cycle boil specimens when compared to similar specimens steam- or kiln-dried at lower temperatures. Strength losses were found in plywood from veneer dried in direct-fired dryers heated by either gas or oil, and from veneer dried in an electric oven.

2. Wood failure, as measured by the standard D.F.P.A. 2-cycle boil test, was not a reliable indication of glue-bond durability for plywood made from veneers dried at high temperatures. Durability of plywood made from steam- or kiln-dried veneers, when measured by a special 25-cycle delamination test, did show close correlation with wood failure.

3. Veneers dried in oil-fired dryers had the least durable glue bonds, when compared by a 25-cycle delamination test to other methods of drying used in the plywood industry.

4. Sooty surface deposits were found on veneer from three different oil-fired dryers. When this veneer was wire-brushed, durability of glue bonds was increased significantly. Bonds of brushed veneer from oil-fired dryers were less durable, however, than were those of steam-, kiln-, or gas-dried veneer.

5. The water-absorbing capacity of veneer was reduced by increasing the drying temperature with a constant drying time, or by increasing the drying time at a constant temperature. Reduced veneer absorptivity could be a contributing factor in inferior joints because of reduction in wettability of veneer by glue.

Conclusions

The research did not provide positive means for ensuring good-quality exterior-type glue bonds from veneer dried at high temperature, especially those dried in oil-fired dryers. It was not apparent that such bonds have been accomplished consistently by anyone connected with the problem.

What may prove more important, however, were other adverse effects found in veneer dried at high temperatures. Assuming a reliable method can be developed to produce well-bonded exterior plywood from high-temperature-dried veneers, the strength properties of this plywood yet may be substandard. Research underway by the D.F.P.A. should determine the degree of strength loss.

Based on results of the special 25-cycle delamination test, the D.F.P.A. quality-control program for exterior-type plywood appeared adequate for measuring glue-bond durability of plywood made from veneers dried with steam, but inadequate for plywood from veneers passed through high-temperature dryers. It is realized that the 25-cycle delamination test would be quite impractical for quality control, but in experimental work, it appeared reliable.

Findings from the study do not contradict recommendations of the Technical Committee of the West Coast Adhesive Manufacturers, who advise that successful hotpress bonding of veneers dried in most high-temperature dryers can be accomplished by modification of dryer design (1). Increased dryer length, multi-zoned heating, and temperature control of each zone are mentioned as recommended design changes. There is evidence to suspect that oil-fired dryers, however, could produce veneer with poor gluability, even when operated at lowered temperatures.

Solution to the problem of making high-quality exterior plywood from high-temperature-dried veneers can result from combined efforts of many organizations, including dryer manufacturers, glue companies, public research laboratories, the Douglas Fir Plywood Association, and plywood mills with direct-fired dryers. In the final analysis, a compromise will have to be made between such factors as production rates, economics, and product quality.

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Discussion

Robert Ripley (Douglas Fir Plywood Association): I would like to ask a question concerning the delamination test. As I understand it, your delamination test largely measured wood failure rather than glueline failure, and it occurred to me that perhaps the term "delamination" was not just the right one.

Mr. Currier: The 25-cycle test was used for comparison purposes. In some cases the failure was entirely in the glueline, but in other cases the failure was in the wood and might better be described by some term other than delamination.

Mr. Ripley: The Douglas Fir Plywood Association considers delamination a failure of the glueline, that is, in the glue, and failure in other portions as wood failures.

Mr. Currier: There could be a distinction there.

Mr. Ripley: I have another question concerning some of the loads shown for the shear specimens. Did you kerf your specimens with respect to lathe check orientation for maximum load?

Mr. Currier: This point was not considered. Kerfing of all specimens was done at random.

Mr. Ripley: This is not a question, but more of a statement. With respect to your findings here that the 2-cycle boil test was not a good indication of exterior durability, I might say that two of our member mills that have oil-fired dryers have been trying to produce exterior type plywood for about one year. Neither mill has been successful in producing plywood that meets D.F.P.A. specifications.

Anon: Did you run some analyses on the gases? If so, what is their composition? I feel that you have two reactions there. The first is due to hot air where the reactions on wood are known. You mentioned stability being increased and hygroscopicity being decreased, but when you start to deal with gases, there may be other reactions. There may be sulfur dioxide and other gases present which will react with the wood, and which will change the composition of the wood.

Mr. Currier: We did not run any tests as far as analysis of the drying atmosphere either in our oven or in commercial dryers. I have not seen such analyses, although some may have been made.

Anon.: Have the glue companies developed a glue that will bond wood that is in this condition?

Mr. Currier: All the glue companies have had a problem on this, and I understand it has been pretty hectic. As far as I know, such a glue hasn't been developed. There may be someone here who can say something about this.

N. S. Perkins (Douglas Fir Plywood Association): Mr. Chairman, I would like to make an observation or two. First, I would like to congratulate Mr. Currier on a fine piece of work and an excellent presentation. To reinforce what Mr. Ripley said, first I might say that the so-called D.F.P.A. test was not originated by the D.F.P.A. It is an old Forest Products Laboratory test, and perhaps it predates that. What we have done over the years is to establish a correlation between failure after the two-cycle boil test, and durability in the field. Field durability was determined by examination of some 12,000 to 14,000 specimens of plywood that have been on our test fences since about 1939. Now, if you do something to the veneer to weaken its properties, you may never get failure in the glueline. Actually, that might happen in service because, under changing humidity conditions, the glueline would not be stressed. The wood itself might actually break, but this expansion and contraction of the crossbandings, if the wood is very weak, apparently will not put sufficient stress on the glueline to break it. This is not a criticism of what has been presented. I merely want to point out that, when failure occurs in the wood, that has nothing at all to do with durability of the glueline. Furthermore, if these pieces are subjected to a 25-cycle test, you are actually doing something to the wood. I am not a chemist and I don't know whether you are actually digesting it or not. Some ten or fifteen years ago, we used a 20-cycle test in trying to get one that would be a little more discriminating than the 2-cycle test. We were unable to come to any conclusions except that we thought we were cooking or digesting the wood somewhat. So keep in mind, please, that the D.F.P.A. test, so-called, is not a measure of the boil resistance of any glue. It is merely a correlation between actual performance in the field and the rather quick 2-cycle boil-dry test. Thank you.

Mr. Currier: Thank you for your comments. I think you will find in the written report that I did go into the background and theories behind your test and how it was developed. In view of time limitations, I left out the details in my oral presentation.

Ken Guenther (Pope & Talbot): I don't know too much about drying, but I am familiar with humidification. When you speak of drying-temperature variability across the dryer, are you speaking of perpendicular to the passage of the material?

Mr. Currier: That was the orientation.

Mr. Guenther: Not parallel? Not from end to end?

Mr. Currier: No, this particular test was across the dryer. There have been others that were run end to end.

Mr. Guenther: Since something is accomplished in humidification by varying conditions along the cycle or parallel to the movement of the material through a humidifier, could there not be something in the drying also whereby different temperatures at different times would affect the end product?

R. K. Stensrud (Reichhold Chemicals, Inc.): I have a comment on that same thing. I notice you mentioned that temperatures over 400° were what you considered high-temperature drying. We feel that the placement of temperatures throughout the dryer is of far more importance than the actual temperature. We have some very conclusive evidence that an oil-fired dryer set up in the ordinary manner will produce plywood with no durability. If that same dryer is set up with a changed time-temperature relationship, it will produce veneer that can be glued satisfactorily. In other words, change a variable such as the point at which the air enters the dryer, the temperature of that air at that time, the moisture content of the veneer at that time and so forth.

Mr. Currier: That goes along with the idea already mentioned of modifying the temperature controls and other features of high-temperature dryer

A Prediction Equation for Veneer Drying Schedules[1, 2]

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A simple method of estimating veneer drying schedules from trial runs has been developed on the assumption that moisture content-time drying curves can be represented by a quadratic equation. Theoretical families of curves, representing a wide range of initial moisture contents and drying rates, can be derived. The validity of these graphs, used for estimating schedules and in quality control work, was determined by comparing predictions with actual drying data.

OF THE SEVERAL METHODS USED to dry veneers, the use of high-temperature continuous dryers accounts for more footage than all other methods combined. High production rates coupled with low costs are the most important advantages of this method as compared to other methods, such as drying in low-temperature compartment and progressive kilns and in steam-plate drying.

Economical and trouble-free manufacture of the dried veneer into plywood and other products demands close control of the moisture content of the veneer as it comes from the dryer and in all subsequent operations. Many of the difficulties encountered in plywood manufacture, such as warping and twisting, blisters, and poor glue bonds, can be traced directly to undesirable moisture content or to excessive variation in moisture content. Control of this moisture content necessitates adequate control of the dryer through the use of some sort of drying schedules—time schedules for continuous dryers.

Good drying schedules must have the following characteristics:

1. They must be reasonably accurate.
2. They must be based upon information usually available to the dryer operator or information easily and quickly obtainable by the operator.
3. They must be easy for dryer operators to use.

The purpose of this paper is the development of a technique for establishing drying schedules that conform to the above criteria.

Review of Literature

Green veneer, as it comes from the lathe or clipper, contains a large amount of water. This amount varies from 30 to 250 per cent, based on the oven-dry weight of the wood (1)[3]. Most of this water must be removed in the drying operation, because the optimum moisture content for veneer in use is generally less than 10 per cent.

The absolute moisture content of wood is dependent upon its specific gravity. At a moisture content of 50 per cent, a cubic foot of wood with a specific gravity of 0.3 and another with a specific gravity of 0.7 will contain 9.36 and 21.84 pounds of water, respectively.

The drying of wood is similar, in many respects, to the drying of other porous solids; hence, a review of some related literature is appropriate.

Sherwood (2) described three mechanisms of drying:

(a) Evaporation of the liquid at the solid surface; resistance to the internal diffusion is small as compared with the resistance to the removal of vapor from the surface.

(b) Evaporation at the solid surface; resistance to internal diffusion of the liquid is great as compared with the resistance to the removal of the vapor from the surface.

(c) Evaporation in the interior of the solid, with or without liquid movement in the interior.

Sherwood applied the above cases to different drying periods that are exhibited when a solid is dried. All very wet solids show a constant drying rate during the early stages of drying. This would correspond to case (a) in which the rate of drying is limited by the rate of evaporation. The first falling rate period is said by Sherwood to be that of case (a) also; however, the decrease in drying rate is attributed to a gradual decrease in the surface actually wetted. If there is a second pronounced falling rate period, it is due to resistance to internal diffusion corresponding to cases (b) or (c).

Bateman, Hohf, and Stamm (3) have listed three means of moisture movement through wood: (a) liquid water above the fiber saturation point, (b) bound water within the cell walls below the fiber saturation point, and (c) as water vapor both above and below the fiber saturation point.

Hawley (4) states that movement of free water is due almost entirely to capillary action.

Buckman and Rees (5) concluded that moisture moves, in wood below the fiber saturation point, as vapor

[1] A 1956 Wood Award Entry. This paper was also presented by Mr. Chrismer at the Spring Meeting of the Carolinas-Chesapeake Section, FPRS, held May 9-10, 1957, at Clemson, S. C. The paper has been substantially revised since that time.

[2] A contribution from project number HM-21 of the North Carolina Agricultural Experiment Station in cooperation with the Southeastern Forest Experiment Station, U. S. Forest Service.

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[3] Numbers in parentheses refer to the Literature Cited at the end of the paper.

across the cell cavities and as bound water through the cell walls. This is the generally accepted theory of the drying of wood at low temperatures (below 212° F.).

High-temperature drying of wood (above 212° F.) in this country is largely confined to the drying of veneer and to the drying of wood chips.

Bethel and Hader (6) state that boiling of free water, in the cell cavities of veneers being dried at high temperature, probably occurs and that most of the water is moved through the wood by vapor diffusion.

Bethel and Hader dried over 300 samples of veneer representing 22 species for the purpose of analyzing the drying characteristics. Drying curves (moisture content per cent over time) were consistently found to be straight lines in the upper portions and curved lines at the lower moisture contents. By making graphic estimates of the first derivative of this curve and then plotting, on log-log paper, the drying rate over moisture content, two or more interesting straight lines were found to exist. A line parallel to the abscissa represented the constant rate period, and the falling rate period was represented by one or two intersecting straight lines with positive slope. Mathematical relationships were developed from these curves to give the required drying time for any desired moisture content.

Fleischer (7) used a different approach in his method of computing drying schedules. He found that rate of drying, in terms of evaporation of grams of water per minute, plotted as a straight line over drying time. From this he derived an equation to determine the time required to dry the veneer to oven dry. Another equation was developed to compute the moisture content at any given time. This equation was found to be parabolic in form. This fact was utilized in transforming the ordinary moisture content —time curve into a parabola with its vertex at 0.0. This form of a parabola can be plotted as a straight line on log-log paper. Thus, only two points were needed to determine the time required to dry to any given moisture content.

Derivation of the Equation for Estimating Drying Time

To be efficiently used, any method of determining drying schedules for veneer must satisfy the criteria listed in the introductory paragraphs. For example, consider the following situation in a commercial veneer drying operation. The dryer operator has a batch of veneer to dry, but he does not know the exact time schedule to use to arrive at the desired moisture

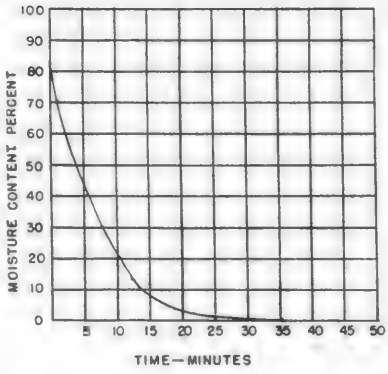

Fig. 1.—Drying curve for 1/10-inch poplar heartwood veneer dried at 300° F.

content. On the basis of the initial moisture content of the veneer and on past experience, the operator selects a tentative schedule and makes a trial run. At the end of this run, the dried veneer is found to contain 7 per cent too much moisture. The question then arises, how much should the drying time be increased to give the desired moisture content.

Two things are known by the operator—the initial moisture content and the time used to dry to a lower moisture content. With this information it would be desirable if the operator could refer to a set of graphs and read directly the drying time that will produce the desired moisture content. Graphs of this type are not available, and it is the purpose of this paper to show how they can be developed.

Examination of a large number of moisture content-time curves constructed from veneer drying data collected at the North Carolina State College Wood Products Laboratory, and of curves found in articles by Bethel and Hader (6), Whippie (8) and others, reveal that such curves are usually of the form shown in Fig. 1.

Further study of the moisture content-time curves revealed that the lower portion of the curve could be adequately described with a quadratic equation of the form:

$$y = a - bx + cx^2$$

where y is the moisture content per cent and x is the drying time in minutes.

The problem as it was originally stated cannot be solved with this information alone. Therefore, the further assumption was made that a quadratic equation would describe the entire moisture content-time curve. This, of course, is not strictly true. A close fit can be obtained, however, in the moisture content range between 2 and about 30 per cent. Since this is the area of interest in veneer drying, any deviations in the curve above 30 per cent or below 2 per cent moisture content will be of little consequence.

A convenient form of this quadratic relationship was derived as follows. Let M_i be the initial moisture content of the green veneer, M_d the moisture content after drying for time T_d, and T_e the drying time required to reach equilibrium moisture content, M_e[4] (b and c are constants appropriate to the equation). T_e is the unknown value. The equation relating moisture content and time is:

$$M = M_i - bT + cT^2 \quad \text{---- (1)}$$

Using the known values, M_i, M_d and T_d:

$$M_d = M_i - bT_d + cT_d^2 \quad \text{-- (2)}$$

$$b = \frac{M_i - M_d + cT_d^2}{T_d} \quad \text{---- (3)}$$

This gives b in terms of known values except for c. However, c may be obtained as follows. If we take the first derivative of the general equation (1), we obtain the general expression for the rate of drying:

$$\frac{dM}{dT} = -b + 2cT \quad \text{------- (4)}$$

In strict theory, the moisture content asymptotically approaches the equilibrium moisture content, M_e. In the present case, however, the parabolic form that is to be used as an approximate drying curve will reach a minimum value, M_e, at a definite time, T_e, beyond which time it will increase (mathematically). Thus it is necessary to assume that the drying rate is zero at (M_e, T_e). On the basis of this assumption, we next substitute T_e for T in equation (4) and obtain:

$$0 = b + 2cT_e \quad \text{---------- (5)}$$

$$c = \frac{b}{2T_e} \quad \text{---------- (6)}$$

into which b from equation (3) may be substituted, to give:

$$c = \frac{M_i - M_d + cT_d^2}{2T_eT_d} \quad (7) \quad \text{-----}$$

Solving for c, we obtain:

$$c = \frac{M_i - M_d}{2T_eT_d - T_d^2} \quad \text{-------- (8)}$$

which gives c in terms of known moisture contents and times with the exception of T_e. Substituting this expression for c into equation (3) and simplifying, we also obtain a similar expression for b.

$$b = \frac{M_i - M_d}{T_d} + \frac{M_i - M_d}{2T_e - T_d} \quad (9)$$

[4] For the problem at hand, M_e may be assumed to be zero percent moisture content, since veneer dryers normally operate at high temperatures. For the sake of completeness, however, and also for possible additional applications, the solution will be carried out for the general case in which M_e may have other values as well as the value of zero.

We now have T_c as our only unknown. Returning to equation (1) and expressing it in terms of T_c, we obtain:

$$M_c = M_i - bT_c + cT_c \quad \text{---} \quad (10)$$

Substituting the values for c and b from equations (8) and (9) into equation (10) and simplifying, we reduce the expression to:

$$(M_d - M_i)T_c^2 + (2M_iT_d - 2M_cT_d) + T_d^2(M_c - M_i) = 0 \quad \text{-----} \quad (11)$$

This is a quadratic equation in T_c in the standard form $ax^2 + bx + c = 0$ and may thus be solved by use of the standard formula for such solutions. When this is done and simplifications are made wherever possible, we obtain the expression:

$$\frac{T_c}{T_d} = \frac{\sqrt{M_i - M_c}}{\sqrt{M_i - M_c} - \sqrt{M_d - M_c}} \quad \text{--------} \quad (12)$$

and

$$T_c = \frac{T_d\sqrt{M_i - M_c}}{\sqrt{M_i - M_c} - \sqrt{M_d - M_c}} \quad \text{--------} \quad (13)$$

Thus we now calculate the time, T_c required to reach the equilibrium moisture content, M_c, given that we know the initial moisture content, M_i, and also some moisture content, M_d, that was obtained after a given time of drying, T_d.

Returning to equation (12), it can be seen that T_d and M_d may represent any point on the parabolic curve, since no restrictions have been placed upon them in the previous calculations [the same is not true for (T_c, M_c) since the slope was specified as being zero at this point]. Therefore, we may replace T_d and M_d in equation (12) with symbols representing any desired point, (T_x, M_x) on the curve. Inverting and solving for T_x, we obtain:

$$T_x = T_c \frac{\sqrt{M_i - M_c} - \sqrt{M_x - M_c}}{\sqrt{M_i - M_c}} \quad \text{--------} \quad (14)$$

Substituting for T_c from equation (13) and simplifying, we obtain:

$$T_x = T_d \frac{\sqrt{M_i - M_c} - \sqrt{M_x - M_c}}{\sqrt{M_i - M_c} - \sqrt{M_d - M_c}} \quad \text{--------} \quad (15)$$

Equation (15) represents the final solution of our particular problem, and is the only expression required for a mathematical estimate of the desired drying time. It also serves for the determination of T_c, since this is only a specific value of T_x.

If the equilibrium moisture content, M_c, is zero, as can be assumed in most applications to veneer drying, the expression is simplified somewhat to:

$$T_x = T_d \frac{\sqrt{M_i} - \sqrt{M_x}}{\sqrt{M_i} - \sqrt{M_d}} \quad \text{-} \quad (15a)$$

Use of the Mathematical Equation for the Determination of the Drying Time Required

We now have a single equation for estimating the drying time setting required for a high-temperature veneer dryer. This equation is as follows:

$$T_x = T_d \frac{\sqrt{M_i} - \sqrt{M_x}}{\sqrt{M_i} - \sqrt{M_d}}$$

where: M_i = the initial moisture content of the green veneer;

M_d & T_d = the moisture content, M_d, obtained after a trial run of time T_d;

M_x & T_x = the moisture content, M_x, for which the proper time setting, T_x, is desired.

To illustrate the use of this equation, a sample problem should prove helpful. Assume that, in a given trial run, a veneer dryer is set for ten minutes and a sheet of veneer is run through. The initial moisture content of the sheet was 81 per cent and it dries down to only 21.5 per cent. What time setting should be used to obtain a desired moisture content of 6 per cent for subsequent sheets? Substituting into our equation, we have:

$$T_x = 10 \frac{\sqrt{81} - \sqrt{21.5}}{\sqrt{81} - \sqrt{6}} = 15 \text{ minutes}$$

Use of Graphs for the Determination of the Drying Time Required

For plant production applications, the preceding calculation may be too laborious and time consuming because the operator needs to be able to estimate a new dryer speed as quickly as possible after he has made a trial run. For this reason, then, the next logical step was to construct a series of curves that would cover a wide range of initial moisture contents and a range in drying rates.

The range in initial moisture content selected was from 60 per cent to 180 per cent. This was divided into increments of 20 per cent, and a family of quadratic curves was plotted for each increment. The curves were evenly spaced over a range of time from about 10 minutes to about 65 minutes. A total of seven families of curves were thus constructed, and it was felt that the above limits would cover almost all schedules required in veneer drying.

Due to limited space, only one of those families of curves is reproduced here. It is expected that the entire series of graphs will be published by the North Carolina State College in a separate bulletin.

Equation (14), simplified by the fact that M_c becomes zero, was used to calculate locations of the points on the curves. In using this equation, equal increments of time were selected as the times required to reach 0 per cent moisture content. For example, in constructing Fig. 2, the curves for an initial moisture content of 80 per cent, 12 curves were drawn that reached 0 per cent every five minutes from 5 minutes to 60 minutes. The curves, so calculated, are a family of parabolas that crosses the y–axis at the same point and have their vertices equally spaced on the x–axis.

The graphs are extremely simple to use. To illustrate, suppose that a point is selected from the curve of Fig. 1. For example, after 10 minutes of drying, the moisture content is 21.5 per cent. What is the time required to dry to 6 per cent? Referring now to the family of curves in Fig. 2 that crosses the y–axis at 80 per cent (the sample has an initial moisture content of 81 per cent), the known point is located

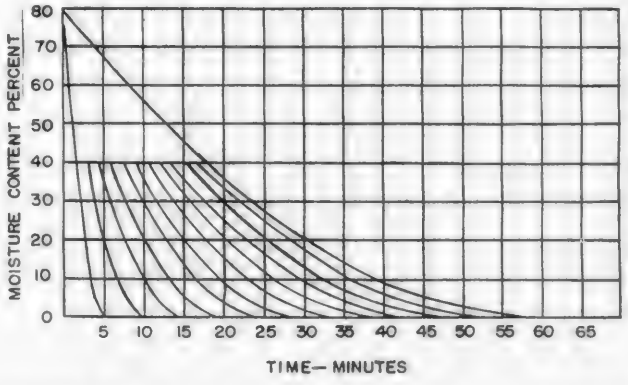

Fig. 2.—Theoretical drying curves for veneer with an initial moisture content of 80 per cent.

with the coordinates (10, 21.5). By following parallel to the nearest curve down to where it crosses 6 per cent, the time required to dry to this moisture content is read directly as 15.5 minutes. This can be checked by referring to the actual data curve in Fig. 1. This indicates that the veneer reached 6 per cent after 16 to 17 minutes of drying time.

The accuracy of the theoretical curves depends to a large extent upon the moisture content that results from the trial run. Generally, if this moisture content is below about 30 per cent, the curves are accurate enough for practical purposes. This was determined by taking actual drying curves, representing a wide variety of species, thicknesses, initial moisture contents, and drying temperatures, and selecting a point on the curves below 30 per cent moisture content and noting the time required to reach that moisture content. The theoretical curves were then used to predict the drying time necessary to reach 6 per cent moisture content. These predictions were then compared to the time required according to the actual drying curves. The errors in most cases were not greater than two minutes. The corresponding errors in moisture content were about one to two per cent absolute value. The predicted drying times were usually too long; consequently, the moisture contents were too low. It is felt that these small errors are not important in practical application.

It must be stressed that the use of the method presented in this paper is intended only for the estimation of the drying time required. Furthermore, the application of this method requires that the results of a trial run (or its equivalent) be available. It is necessary that this required prior information be obtained for a specific batch of veneer (the sheets of which must have comparable drying characteristics, as determined by initial moisture content, species, thickness, and so forth), and that the drying conditions, other than time, be the same in the trial run as in the contemplated run. For example, in running a batch of veneer, the moisture content may be satisfactory but the production rate may be lower than desired. To speed up the output, the temperature of the dryer may be increased to permit a lower time setting. The method presented here does not indicate the amount by which the time can be cut. This must be guessed and the resultant moisture content noted. Then, if an undesirable moisture content is obtained after the temperature has been increased and the time reduced, the correct time can be accurately estimated with the method presented in this paper.

Practical Application

Some comments here, on methods used to obtain the necessary information to use the curves, are appropriate. As was stated before, the dryer operator needs to know the initial moisture content of the green veneer, and the moisture content after a period of drying. The following is a method which is recommended to get this information:

Before making the trial run, select several representative sheets of green veneer and weigh them. Write the weights on the respective sheets and run them through the dryer. Weigh the sheets again as they emerge from the dryer. Determine the moisture contents of the dried sheets of veneer through the use of a moisture meter or by the oven-drying method.

The initial moisture content of the sheets before drying can be calculated from the following equation:

$$M_i = \frac{W_i\,(M_d + 100)}{W_d} - 100$$

where M_i = initial moisture content of veneer as it goes into dryer;

W_i = weight of the green sheet of veneer as it goes into the dryer;

W_d = weight of the dried sheet of veneer as it comes from the dryer;

M_d = moisture content per cent of the veneer as it comes from the dryer.

The initial moisture contents of the several sheets should be averaged, as should the moisture contents after drying. We now have the necessary information to enter the graphs and estimate the drying time necessary to reach any moisture content.

If the next lot of veneer to be dried is slower in drying than the lot currently being run, then all this work can be done without interrupting the flow of veneer through the dryer. For example, suppose that the operator is drying red gum sapwood 1/16 inch thick. The next batch of veneer to be dried is red gum heartwood 1/16 inch thick. Several sheets of heartwood can be run with the sapwood to get the necessary information to change to a new schedule. The calculations and graph-reading can all be done ahead of time so that the new dryer time can be set as soon as the new batch is started.

Another place in which this method of estimating drying schedules should find useful application is in the use of control charts at the dry end of the dryer. These charts are usually $\overline{X}$ and R charts on the moisture content of veneer. If the charts go out of control due to some factor that changes the drying rate of the veneer, the graphs can be used to establish a new dryer schedule to bring the drying process back to a desired state of control.

Several precautions should be taken to achieve effective use of this method of determining drying schedules for veneer. One of the most important is segregation of green veneer into batches that have similar drying rates. This has been effectively pointed out by Bethel (9), and the main points are summarized here. The most important factors in veneer that determine drying rates are species, heart or sap condition, thickness, and initial moisture content. For drying purposes, veneer should be segregated in accordance with these criteria. While it is not practical to check the initial moisture content of green veneer and separate it on this basis, several things can be done to minimize this variation. One of these is the use of a log inventory system, which will minimize yard storage time and allow the oldest logs to be used first.

Another factor that influences the initial moisture content is the handling of the veneer between the lathe and the dryer. This handling and storage time should generally be kept at a minimum. Measures should be taken to prevent the drying of the ends and top sheets in the green stack.

In summary, then, to be able to determine drying schedules accurately and effectively control the variation in moisture content of the dried veneer, the green veneer must be separated into batches that have similar drying rates.

Conclusions

Accurate veneer drying schedules can be determined by use of the method presented in this paper. It was shown how theoretical drying curves can be constructed so that the dryer operator need only make a few simple calculations and read the graphs to determine drying schedules quickly and effectively.

The curves can also be used to help maintain a state of statistical control when control charts are used on the moisture content of dried veneer.

To use this method, green veneer must be separated into batches with similar drying rates.

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Fire-Resistance Tests of Solid Wood Flush Doors

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The position of the untreated, solid wood flush door in the fire-resistance scale is pictured. Two series of tests, run according to ASTM standards, show these doors to have an effective resistance of roughly half an hour.

DOORS EFFECTIVELY BLOCK THE PROGRESS of fire in buildings. The need for fire resistance in doors varies with the occupancy, type and location of the building, position of doors in the building, and other conditions, but in most doors some fire resistance is desirable.

This report indicates the fire resistance that can be expected from door assemblies with commercial solid-wood flush doors. The doors tested had no fire-retardant treated wood or other special design features that are sometimes used to improve the fire resistance of wood doors. The tests described in the report were made at the U. S. Forest Products Laboratory in cooperation with the National Woodwork Manufacturers Association.[2] They include two series of tests: Series A, consisting of four tests made in 1939, and Series B, three tests made in 1955.

[1] Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

The Author: Victor Miniutti received BS degrees in forestry and chemical engineering from the University of Maine, and an MF degree from the Yale University School of Forestry. He has been a Forest Products Technologist in the Division of Timber Processing at the Laboratory for 7 years. He was recently transferred from the Fire Protection Section to the Section of Painting and Finishing.

Door Assemblies

Each door assembly consisted of a solid-wood flush door, a door frame, three hinges, and a lock.

Doors: All doors were made commercially, and were 1-3/4 inches thick and 3 feet wide. Each consisted of solid wood, flush 5-ply construction, with a face and crossband veneer ply glued to each side of a lumber core. The cores were butt-jointed ponderosa pine blocks bonded together with casein glue. The faces were birch veneer. The doors varied in height, face veneer thickness, species and thickness of crossband veneers, species of edge strips, and types of glue used in bonding the veneers to each other and to the core. Two arrangements of core blocks were employed. Construction details are given in Table 1.

[2] Formerly known as the National Door Manufacturers Association.

Doors P–32 and P–39 (Series A). —These doors were 7 feet high and had wood core blocks 7/8 to 1–1/2 inches wide, with the wood grain parallel to the vertical edge of the door. This core-block arrangement is illustrated in Fig. 1. Edge and end strips were of 3/4-inch birch. Phenolic resin adhesive was used to glue 1/16-inch birch crossband and face plies to each side of the core.

Doors P–33 and P–40 (Series A). —These doors were 7 feet high and had wood core blocks 1–1/4 inches wide glued into stiles, rails and panels. The stiles and rails were 5–1/2 inches wide, and were assembled with dowels at each intersection. This core-block arrangement is shown in Fig. 2. Edge strips were of birch 3/4 inch wide, but no end strips were used. Casein glue was used to bond 1/16-inch gum crossband and birch face veneers to each side of the core.

Doors P–134 and P–135 (Series B). —Door P–134 had ponderosa pine edge strips, and P–135 had birch edge strips, but the doors were alike in all other respects. They were 6 feet 8

Table 1.—CONSTRUCTION DETAILS OF SOLID-WOOD FLUSH DOORS TESTED AT U. S. FOREST PRODUCTS LABORATORY

Door	Size	Faces and crossbands	Veneer adhesives	Core[1]	Edge strips	Frame
P32	3′x7′x1¾″	1/16-in. birch	Phenolic resin	Blocks ⅞ in. to 1½ in. wide	Birch, ¾ in. wide	Steel frame
P39	3′x7′x1¾″	1/16-in. birch	Phenolic resin	Blocks ⅞ in. to 1½ in. wide	Birch, ¾ in. wide	Fire-retardant treated wood
P33	3′x7′x1¾″	1/16 in. birch faces, 1/16-in. gum crossbands	Casein	Blocks 1¼ in. wide in stiles, rails, panels; dowelled at intersections	Birch, ¾ in. wide on sides only	Steel frame
P40	3′x7′x1¾″	1/16-in. birch faces, 1/16-in. gum crossbands	Casein	Blocks 1¼ in. wide in stiles, rails, panels; dowelled at intersections	Birch, ¾ in. wide on sides only	Fire-retardant treated wood
P134	3′x6′8″x1¾″	1/20-in. birch faces, 1/12-in. basswood crossbands	Urea resin	Blocks ¾ in. and 1¾ in. wide	Ponderosa pine	Steel frame
P135	3′x6′8″x1¾″	1/20-in. birch faces, 1/12 in. basswood crossbands	Urea resin	Blocks ¾ in. and 1¾ in. wide	Birch on sides; ponderosa pine on ends	Steel frame
P136	3′x6′8″x1¾″	1/20-in. birch faces, 1/12-in. soft maple crossbands	Melamine-urea resin	Blocks 1¾ in. wide	Birch, ¾ in. wide, on sides; soft maple, ⅝ in. wide, on ends	Steel frame

[1] All cores were butt-jointed ponderosa pine blocks bonded with casein glue.

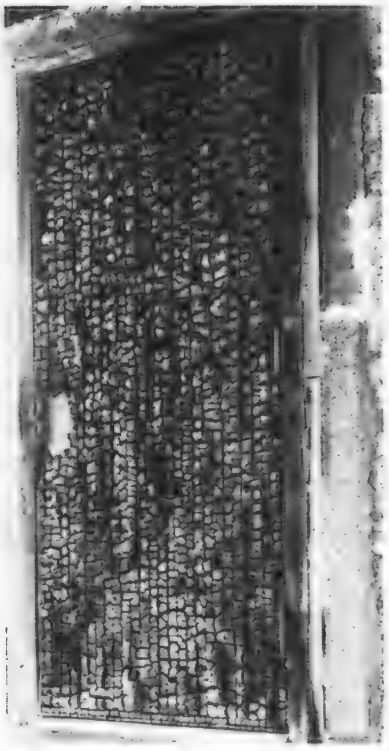

Fig. 1.—Exposed side of assembly P–32 after 40 minutes of fire exposure. The door was constructed with the grain of the core blocks parallel to the vertical edges of the door. Doors P–39, P–134, P–135, and P–136 were also of this type of construction.

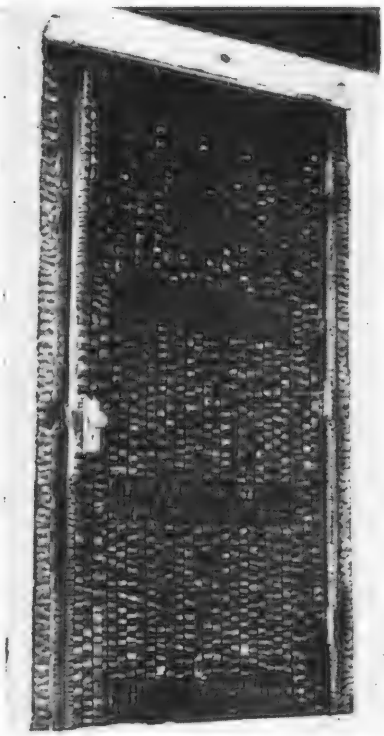

Fig. 2.—Exposed side of assembly P–40 after 38 minutes of fire exposure. The door was constructed with core blocks arranged in stiles, rails, and panels. Door P–33 was also of this type of construction.

inches high and had ¾- and 1-¾-inch wide core blocks, with the wood grain parallel to the vertical edge of the door. This core arrangement is similar to that shown in Fig. 1. The end strips were ponderosa pine. Both edge and end strips were glued to the core with polyvinyl resin. Urea-formaldehyde resin was used to glue a 1/12-inch basswood crossband and a 1/20-inch birch face to each side of the core.

Door P–136 (Series B).—This door was 6 feet 8 inches high and had 1-⅜-inch-wide core blocks, with the wood grain parallel to the vertical edge of the door. This core arrangement is also like that shown in Fig. 1. Edge strips of ¾-inch-wide birch were glued to the core with polyvinyl resin glue. The end strips were soft maple glued with urea resin to 1 ⅝-inch wide ponderosa pine, which was not glued to the core. Melamine-urea resin glue was used to bond a 1/12-inch soft maple crossband and a 1/20-inch birch face to each side of the core.

Door Frames: For the Series A tests, frames of fire-retardant treated wood and 16-gauge pressed steel were used. Two tests were made with each type of frame. For the Series B tests, 16-gauge pressed steel frames bearing the Underwriters' Laboratories label for fire-door frames were used.

Hinges: Three full-mortise, loose-pin hinges of wrought steel were used with each door. In Series A, the hinges were 5 by 5 inches, and in Series B, they were 4-½ by 4-½ inches.

Locks: The locks used in Series A tests were lightweight mortise-case locks with 3-½- by 2-½- by ¾-inch case, ½-inch latch bolt throw, 2¾-inch backset, and 2½- by 7-inch escutcheons. The locks were installed with the center of the latch bolt 39-½ inches above the floor line. The locks used in Series B tests were heavy duty, cylindrical case locks bearing the Underwriters' Laboratories Re-examination Service Label. The locks had a ½-inch latch bolt throw, a 2-¾-inch backset, 2-1/16-inch diameter case, and 2-9/16-inch diameter escutcheons. The locks were installed with the center of the latch bolt 38 inches above the floor line.

Clearance between Door and Frame: In Series A tests, the doors were mounted with clearance between door and frame adjusted to 1/16 inch at the top, 3/32 inch at the sides, and 3/16 inch at the bottom. In Series B tests, the clearances were 1/16 inch at the top and sides were 3/16 inch at the bottom.

Fig. 3.—The vertical fire-resistance furnace at the U.S. Forest Products Lab.

Test Procedures

For each test, a new frame was installed in a 4- by 8-foot opening in the front of the Forest Products Laboratory's vertical fire-resistance furnace (Fig. 3), and a door was hung to swing into the furnace.

The Series B tests were conducted according to American Society for Testing Materials Standard E 152–1, "Standard Methods of Fire Tests of Door Assemblies." One side of the door was exposed to fire, controlled to follow the ASTM standard time-temperature curve, and temperatures were measured within the furnace and on the unexposed side of the door. The hot junctions of the thermocouples within the furnace were enclosed in protecting tubes, as specified in the ASTM standard. Any observation bearing on the performance of the test assembly was noted.

When Series A tests were made, the ASTM had adopted the time-temperature relation for fire tests of building constructions, but had no standard fire-test method for doors. In general, however, the procedure used for the Series A tests was the same as for the Series B tests, except that furnace temperatures were controlled to follow the ASTM time-temperature curve with unprotected thermocouples.

Correction for Use of Unprotected Thermocouples

Because the Series A tests were made with unprotected thermocouples and Series B with protected thermocouples, the need for adjustment to make the two sets of data comparable was considered. In fire-resistance tests in the large vertical furnace with several pairs of protected and unprotected thermocouples in the fire chamber, the protected thermocouples indicated a lower temperature, although the temperature difference decreased as the time increased. These temperature differences were converted to area d-

ferences under the time-temperature urves, and subtracted from the areas nder the Series A time-temperature urves. This gave areas like those that ould have been obtained if protected ermocouples had been used. The eas under the adjusted curves were 1.7 to 14.0 per cent smaller than corsponding areas under the ASTM ndard curve for a 35-minute period. hese differences required a correction the resistance periods recorded.[3] he correction formula given in STM Specification E119–53[4] was plied to allow for the variations om the prescribed furnace temperatres. The corrections thus calculated aried from –2.0 to –4.0 minutes. All mes in this report for Series A tests re corrected times.

Results

Records made during the door-assembly tests are summarized in Table 2. The more important observations are shown in the bar graph of Fig. 4.

Figs. 1 and 2 show the appearance of the exposed side of two Series A doors after test. Figs. 5, 6, and 7 show the appearance of the unexposed side of a door during the test for each type of door frame used in each of the test series.

Discussion

The Assembly: A door assembly tested for fire resistance includes a door, door frame, and door hardware. Each part of the assembly, as well as the intial clearance between door and frame, can affect performance in the test.[5]

Fire Performance Requirements: ASTM Standard E152–41 specifies that the fire test on the assembly shall be continued until failure occurs, or the limit of resistance specified by the submitter has been met. It also states that the test method does not establish ratings or sandards of performance for different uses, because these depend upon service requirements and are under the control of various regulatory bodies. The standard requires that: 1) the test assembly shall have remained securely in the opening during the fire exposure period, 2) openings shall not develop anywhere through the assembly, 3) openings markedly in excess of the initial clearances shall not develop at the outside or meeting edges, and 4) if a transmitted-temperature end point is specified, it shall be considered as a condition of acceptance.

In applying these requirements to fire tests of doors, considerable leeway in judging the time and cause of failure is possible. The sudden swinging or falling of a door into the furnace so that it no longer blocks the opening in the wall would be considered a

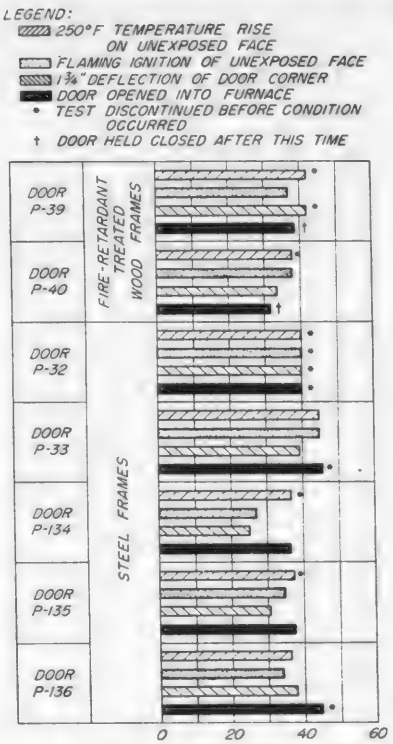

Fig. 4.—Results of fire-resistance tests on flush wood doors.

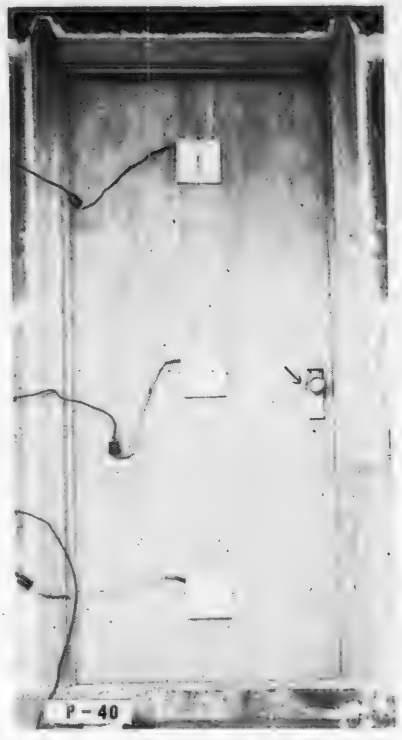

Fig. 5.—Unexposed side of assembly P–40 with a fire-retardant treated wood door frame at 29.4 minutes of exposure to fire, when a hole burned through the door at the escutcheon.

[3] ASTM Standard E152-41 specifies that the accuracy of the furnace control shall be such that the area under the time-temperature curve, obtained by averaging the results from the pyrometer readings, is within 10 per cent of the corresponding area under the standard time-temperature curve for fire tests of 1 hour or less.

[4] The correction can be expressed by the following formula:

$$C = \frac{2I\ (A - A_s)}{3(A_s + L)}$$

where C is correction in the same units as I, I is indicated fire-resistance period, A is area under the curve of indicated average furnace temperature for the first three-fourths of the indicated period, A_s is area under the standard furnace curve for the same part of the indicated period, and L is lag correction in the same Centigrade-hours (3,240 Fahrenheit-minutes or units as A and A_s (54 Fahrenheit-hours or 30 1,800 Centigrade-minutes)).

[5] Other tests at the Forest Products Laboratory not included in this report indicated that untreated wood frames do not develop the full fire-resistance potential of solid wood flush doors.

Table 2.—SUMMARY OF OBSERVATIONS ON FIRE-RESISTANCE TESTS OF SOLID-WOOD FLUSH DOOR ASSEMBLIES[1]

Condition	Fire-retardant treated wood frames		Steel frames				
	P-39 Min.	P-40 Min.	P-32 Min.	P-33 Min.	P-134 Min.	P-135 Min.	P-136 Min.
Intermittent flames between door and frame	35.0	37.4	25.7	35.1	3.3	18.3	15.3
Flaming ignition of unexposed face	36.6	37.4	----	44.8	26.9	34.5	34.0
Hole through door in lock area	24.8	29.4	20.5	27.4	30.0	23.8	27.0
Hole through door away from lock	----	----	36.7	40.2	36.0	37.3	37.1
Temperature rise of 50° F.	25.9	24.7	25.5	21.9	18.6	21.3	20.1
Temperature rise of 100° F.	33.6	34.7	33.8	32.7	26.0	28.3	27.5
Temperature rise of 150° F.	----	----	38.3	43.0	32.6	34.0	33.5
Temperature rise of 250° F.	----	----	----	44.6	----	----	36.2
Top lock corner deflected toward fire:							
½ inch	25.7	29.3	29.7	28.9	13.8	20.7	25.0
1 inch	36.6	31.6	----	36.6	17.9	26.3	31.4
1¾ inch	----	33.4	----	39.2	25.0	30.6	37.9
Door opened into furnace	[2]38.4	[3]31.3	----	----	[4]36.4	[4]37.3	----
Observations ended	41.6	37.6	39.9	45.3	36.4	37.3	44.7

[1] Blank spaces indicate that conditions listed did not occur during test.
[2] The strike fell from the charred wood frame, which released the latch, but the door was intentionally held closed by a wire attached to the door knob.
[3] The latch was loose from the frame, but a wire was attached to the door knob to hold the door closed.
[4] The lock pulled from the door, and the door opened.

failure. Also, flaming ignition of the unexposed face of the door would probably be considered a failure. There is always an initial clearance between all edges of the door and the frame for the passage of hot gases if a positive gas pressure exists on the fire side, and it is not likely that combustible materials will be placed in contact with either side of a door. Therefore, occurrences such as a small hole burned through a door, warping of the door causing limited deflection of the corners into the furnace, or a considerably elevated temperature of the unexposed side may or may not be considered of consequence, so long as the door remains in place and the unexposed side does not catch fire. Because such leeway in judgment is possible, in this report the observations are presented without interpretation as to their responsibility for failure to meet specification requirements.

Fire Performance of Assemblies: In the tests, a small hole burned through the door near the lock in 20.5 to 30.0 minutes. The holes were caused by the heat conducted by the metal locks from the fire side to the unexposed side of the door. When the holes first appeared they were small (Fig 5), and they increased in size slowly (Figs. 6 and 7). These holes seemed to offer little or no hazard, and ignition of the unexposed faces at the holes did not occur during any of the tests.

In all tests, intermittent flames occasionally emerged between the door and frame. These flames were particularly evident during the test of P–134. A gusty wind was blowing on the day of the test, and may have contributed to the more rapid combustion of the pine edge strips and the early deflection of this door. The deflection of P–134 probably would not have been so great under more usual atmospheric conditions.

Fig. 6.—Unexposed side of assembly P–32 with steel door frame after 36.5 minutes of exposure to fire. The hole through the door around the escutcheon first appeared at 20.5 minutes. The face was charred opposite a shrinkage check in the solid core. There was no flame on the unexposed face, and the door still blocked its opening.

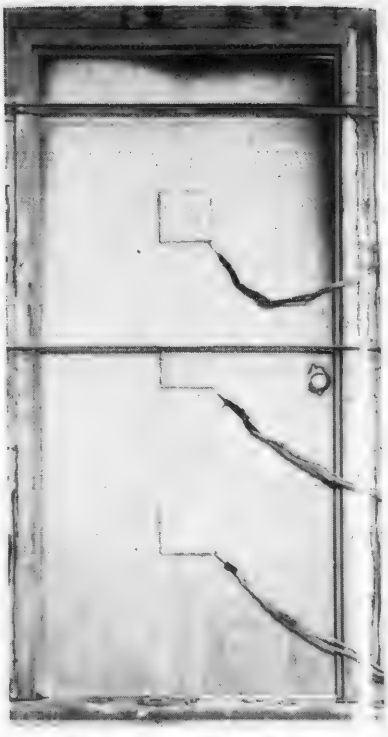

Fig. 7.—Unexposed side of assembly P–135 with steel door frame after 29.5 minutes of exposure to fire. The hole through the door above the escutcheon appeared at 23.8 minutes. Deflection of the upper right corner into the furnace may be seen. There was no flame on the unexposed face, and the door still blocked its opening.

The Challenge Before the Lumber and Plywood Industries[1]

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Even though lumber and plywood are evolving into stable, integrated operations, losses are still too high. Only 34 per cent of the total fiber received at the sawmill becomes lumber, and the percentage rises only to 43 at the plywood plant, where 35 per cent of the best veneer is sanded away. Big savings can result only if the many details are improved.

WE ARE IN ONE OF THE MOST INTERESTING periods of the log conversion industry. We are witnessing the exodus of the "hit and run" method of operation, and are watching the unfolding of stable, integrated manufacturing units. The "hit and run" type of manufacture is characterized by the extravagant use of raw material and labor, by careless logging practices, by ghost towns, by unstable communities. The stable, integrated operations are characterized by more careful logging, the conversion of logs into paper, lumber or plywood, depending on which method will produce the greater return, by the use of improved handling methods to reduce labor, by better tooling to reduce waste, and by the diversion of that material from the sawmill and plywood plants which is not suitable for lumber or plywood for chips, for briquetted fuel, for bark flour, and many other specialized products.

To drive home the magnitude of this problem, look at the following break-down of the utilization of wood fiber brought in the form of logs to the sawmill and plywood plants. These figures are not absolute—they will vary according to the size, species, quality of log, and the character of the conversion plant. For the purpose of sizing up the magnitude of this problem, they are sufficiently accurate.

Sawmill Material	Per cent of total
Bark	9.1
Saw dust	15.3
Shavings	8.9
Edgings and trim	33.1
Shipped as dressed lumber	33.6
Total	100.0

Plywood Material	
Bark	11.8
Log trim	2.1
Core and spur loss	10.3
Clipper loss	17.4
Veneer and panel trim loss	11.5
Sander dust	3.9
Material shipzd as plywood	43.0
Total	100.0

25% LEFT IN THE WOODS
8% bark, trim & sander dust to fuel etc.
30% TO PLYWOOD
25% tops, stumps & sound portions of culls
13% plywood
9% log trim, clipper loss & cores to pulp
10% bark, sawdust & shavings to fuel or other products
15% lumber
20% slabs, edgings & trim to pulp
45% TO SAWMILL

Fig. 1.—Sample utilization of a tree in western Oregon, roots, limbs, and branches excluded.

The challenge that lies before us is that, currently, we ship from a sawmill producing dressed lumber, 33.6 per cent of the fiber, and from a plywood plant producing sanded plywood, 43 per cent of the fiber brought in from the woods in the form of logs.

In a plant producing 100 M. board feet of lumber daily, if one per cent of the raw material can be saved, it would amount to $8,000 per year. This means that, if we can improve sawmilling practice so that we save 0.01 per inch of thickness, it will amount to $8,000 annually; that if we buck logs so that we average 6 inches more of log lengths out of 50 feet of material, we are saving $8,000 a year.

To go after these percentages that pay off so well is not a simple nor an easy job. Results can be accomplished only through infinite attention to detail. It involves better logging practice to prevent stump pull, cutting true, falling to minimize breakage, close supervision of bucking lengths, careful yarding practice, the elimination of tong damage, and good storage practice.

In the sawmill, the selection of equipment and layout has become a complex problem. Most sawmills get peewee logs, big low-grade logs, and big high-grade logs, as well as species not suitable for plywood. A high per-

Fig. 2.—Weyerhaeuser's Springfield integrated operation built around a pulp mill, a sawmill, and a plywood plant. Plants are tied together with conveyor systems, and leftovers from one plant become raw material for another.

[1] Presented at the Spring Meeting of the Pacific Northwest Section, FPRS, held May 13-14, 1957, in Roseburg, Ore.

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centage of the "chuckable" logs that grade No. 2 sawmill and practically all of the No. 2 and No. 3 peelers no longer find their way into the sawmill. Sawmills now must have the flexibility to handle this variation in logs, and convert low-grade logs into lumber profitably. At the same time, they must be able to take the peelers, which produce deep clears when the market justifies, and convert them into lumber when the conversion profit is greater in the sawmill than in the plywood plant.

In addition to the problems of engineering a sawmill to suit the character of the logs now found in the normal sawmill, of getting the maximum lumber return through thinner saws, of more precision cutting, and of the use of hydraulic, air, steam and electrical devices to increase the output per man hour, there is the problem of by-products development.

There are many ramifications in these fields that are contingent upon markets, life of the operation, size of the operation, capital available, species, and many local conditions. Perhaps the biggest step in progress in these fields is the separation of the bark and wood fiber through the use of log barkers. The fact that we now have the bark isolated from the wood fiber in many plants encourages the intensive study of methods of utilizing bark. Considerable work has been done in isolated instances in this field. Some proprietary developments give every indication of being very profitable.

Bark, as a source of wax, chemicals, cork, glue extender and many other products, has a terrific potential, and, industry wide, the field is virtually untouched. The conversion of clean wood to chips has become a general practice in the sawmill industry. We still have no good way to utilize saw dust and shavings for other than fuel.

A basic change in sawmilling, which is unconsciously creeping into the industry, is that sales realization must be increased, not through the increase of cut, but rather through the increase of sales return per M of log scale. For instance, the sales return for boards and dimension is a very competitive, narrow-margin proposition. If through smart planning, we can take this material and make laminated timbers, so that we can make use of the potential quality of the material to advantage in built-up sizes impossible to produce in the mills in well-seasoned condition, we accomplish many things. We give the customer a better product. We increase our total sales value without creating a greater drain on our standing timber. We provide for more employment and more stable communities. We return a greater profit to our ownership.

Let us turn to the late comer to the timber conversion field—the plywood industry. It has been a very profitable industry. It has been set on a pedestal, but when we examine it critically from a manufacturing standpoint we find tremendous room for improvement in labor, in volume, and in quality recovery.

One of the most startling things in the plywood industry is the way we use "A" grade, the highest grade in veneer. We pay over $100 for No. 1 peelers. Half of these No. 1 peelers is core material worth some $50.00 per M. A fair value for this "A" grade in logs is $170.00 per M. We cut it to 1/10 inch to stretch it as far as possible. We have a good side and a poor side. We assemble it into a panel with the good side out. Then we sand off 35 per cent of this material, the best veneer we make, and burn it up.

Another amazing thing in the plywood industry is that one per cent of the raw material per shift per year in a plant producing 100 M feet of 3/8's per shift, is worth $10,000. Face veneers in Doluglas-fir are frequently cut 1/10 inch; core stock is cut up to 5/16 inch. Yet, in an industry where one per cent, worth $20,000 per year on a two shift basis, varies from 0.001 to 0.003† in the thickness of a sheet, we very seldom see a micrometer.

It is time to be brutally honest with ourselves in the plywood business. Our veneer is poorly cut. It is too loose, too rough; we have too much thick and thin; we allow too much for shrinkage; we use too much hand labor; we have too much breakage. We use too much glue, and perhaps most important of all, we are too careless of values of veneer. Too much "A" grade is used for core, too much "C" grade is used for "D" grade. We throw money away blithely and are not aware of it.

Working ourselves out of this situation does not involve bringing in our first line of supervision and "laying down the law." It's not that simple. Each of our problems must be carefully analyzed. Simple controls must be set up so that we known quantitatively the magnitude of our weaknesses; then we must start working out our answers and be able to measure the progress we are making.

Perhaps the most important single item is balancing orders with the quality of the logs. It is essential that the potential of the logs in the pond, from the standpoint of grades, be balanced with the orders. A good rule of thumb is to remember that a per cent of "A" grade used for core or back that is not paid for as "A" grade means a loss in profit of $1.00 per M feet of production in profit.

There are many other interesting approaches to improving the situation in the plywood industry. Without enlarging on them, here are a few:

1) The possible use of steaming of blocks to improve the quality of veneer.
2) Slower clipping to improve grade.
3) The use of mechanical handling equipment such as lifts, feeders, and so forth, to reduce labor and breakage.
4) The reduction of compression in the hot presses.
5) Reduction of sanding allowance at the drum sander.
6) The more general adoption of electrical, hydraulic, and air-operated controls.
7) Improved techniques in the use of low-grade materials through the use of better patching methods and over-lays.

These and many other problems are confronting the plywood industry, and many people and organizations are working on them. We should set an attainable goal in front of us—some target at which to shoot. As a starting point, consider these:

a) A yield of 2.6 M square feet, 3/8-inch basis, per M log scale.
b) A production of 126 square feet 3/8-inch basis per man-hour.
c) An order file balance with the log potential.

This is part of the challenge that lies ahead of us as sawmill and plywood manufacturers. The answer lies not primarily in materials and machines, but in our ability to attract to our industry men with the vision to see these problems, men with the analytical ability to work out the answers, and men with the intestinal fortitude to put these answers into our production lines.

A New and Revolutionary Method of Allocating Costs to Veneer by Grades[1]

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A new method of cost accounting for plywood is described. The author feels that the ⅜-inch basis is inadequate because it does not recognize cost differences due to grades of panels produced. The new method consists of Cost Allocation Factors based on veneer grades, plus prorated indirect costs.

ALMOST FROM THE BEGINNING, the plywood industry has very generally used a method of cost accounting referred to as "Cost Basis ⅜ inch". The production is converted to the equivalent of ⅜-inch plywood panels, and the converted production in terms of units of 1,000 feet divided into the dollar costs; this results in the cost per M basis ⅜-inch.

This method is almost universally used. No one seems to know how it originated, but it seems likely that it stems from the fact that originally only ⅜-inch panels were made. In those early days, cost accounting was simple because only one item was produced. As other grades and thicknesses were added, plywood companies resorted to this method of converting the production to units equivalent to ⅜-inch panels.

Regardless of how this system originated, it is inadequate, because it fails to recognize cost differences due to grades of panels produced. Such average costs have little meaning or significance because there is no such thing as a ⅜-inch panel; it is not made, it is not sold; it is a phantom item that does not exist. Unless and until a plywood panel is identified as to its grade as well as its thickness, it cannot be identified with a selling price.

It might well be argued, with some small degree of merit, that converting production to the ⅜-inch equivalent is for the purpose of recognizing differences in the cost of plywood panels. This argument is valid for only a very few elements of cost; most of the elements of cost do not increase in direct relationship to the thickness of the panel. In other words, even when those elements of cost that vary according to grade are completely ignored, it is impractical and unrealistic to attempt to relate the cost of plywood panels directly to the thickness of the panel. The more important cost differences that are related to grades of plywood panels will be discussed later in this paper.

[1] Presented at the Spring Meeting of the Pacific Northwest Section, FPRS, held May 14, 1957, in Roseburg, Ore.

The plywood industry has made tremendous strides in the last 20 years in the improvement of the machinery it uses to produce veneer and plywood panels. It has also made great strides in the management of timber lands, and in the use of waste materials from lumber and plywood mills. New machines and new processes have been invented that have made old equipment and old processes obsolete. This is not only a growing industry in terms of the volume of its output, but also in terms of its progress by the use of more scientific methods. If one were to make a careful study of the progress made by this industry in the areas mentioned, the differences today compared with 20 years ago would be surprisingly great. This is still a new industry, and its progress along scientific lines will probably be even greater during the next 20 years.

Cost Accounting Has Remained Static

On the other hand, insofar as cost accounting procedures are concerned, there has been very little, if any, progress in this industry in the last 20 years. The method of determining cost basis ⅜-inch is still essentially the same as it was 20, or even 30 years ago. It may be also be asserted, without fear of contradiction, that this method is obsolete. The word "obsolete" means that it has outlived its usefulness; that new and better methods are available. It is obsolete in the sense that there is a new and better way of determining costs than the traditional cost basis ⅜-inch method. It is also inadequate, because it fails to show the management the grand total cost to make and sell every item produced, so that the grand total cost of each item can be compared with the selling price of the same item. Nothing short of this objective will be satisfactory to a modern, progressive management team.

Every plywood panel that sells for a different price has a different cost. These differences are due to the thickness, and to the quality of the veneer used, particularly as to the face and back surfaces of the panel. All these differences in cost must be recognized in order to determine the grand total cost to make and sell every item produced. Since the cost basis ⅜-inch method fails to show the cost of any plywood panel, it is wholly inadequate.

Author's Note: This article is not intended to be a complete treatise on a unit cost finding system; it is restricted to a method of determining the cost of veneer by grades. The article contains some additional material designed to show how the cost of veneer by grades fits into the general scheme of unit cost finding.

Details Necessary, But May Be Minimized: The cost finding system advocated here involves a substantial amount of detail, but most of it is directed to a useful purpose, which is to determine the grand total cost to make and sell every panel, by grade and thickness. When numerous items are made, a considerable amount of detail is necessary. Most plywood companies produce from 50 to several hundred different panels, all of these panel differences being related mostly to either the grade or thickness, or both. The details necessitated by the number of items produced are unavoidable. On the other hand, the burden of these details can be and has been minimized. In the cost-finding system advocated here, there are only 13 elements of cost shown in the unit cost sheet for panels. It is significant that only a few of these elements of cost amount to less than 50¢ per M, and most of them are from $1.00 per M up. In other words, the number of the elements of cost have been minimized, in order to be able to show the cost for every grade and thickness of plywood panels produced, without making the detailed computations too burdensome.

The Intrinsic Grade Values of Veneers Must Be Recognized: The price of a plywood panel is determined very largely by its value or usefulness to the ultimate user. The value of the panel to the user is determined by its construction; that is to say, its strength, and the quality of the two surfaces.

Let us take a simple example of two plywood panels: A ¼-inch "AA"

panel might sell for $95.00 and a 1/4-inch "AD" panel might sell on the same price list for $70.00. Here is a difference of $25.00, and at times in the past this difference in selling prices has been as much as $30.00 per M. The difference in construction between these two items is due entirely to the fact that the "AA" panel has an "A" sheet on the "back", whereas the "AD" panel has a "D" sheet on the back. In terms of actual identifiable costs, the "A" sheet probably did not cost any more than the "D" sheet; certainly, it did not cost $25.00 per M more. As a matter of fact, it is possible that an "A" sheet on a particular panel may have an identifiable cost that is less than the "D" sheet on a particular panel. This might be true if, for example, the "A" sheet required no patching, and if the "D" sheet were made by edge-gluing three strips of veneer.

In addition to the cost of the logs themselves, there must be included all the costs of processing veneer through the green end, and also the labor cost of preparing veneer sheets for use in a panel. This veneer preparation labor means drying, edge gluing, patching, and other costs to the point where the veneer sheets are completely prepared and ready to be used in a panel. In other words, the total cost of veneer to the glue spreader must, at this point, be allocated to the veneer production, by grade and thickness.

This procedure is necessary for two important reasons: (1) for practical cost accounting purposes it is impossible to identitfy and allocate actual costs to veneer by grade and thickness as it moves through these processes, and (2) even if it were possible to follow these veneers through these processs, making each grade and thickness absorb its actual share of the cost, the end result would not be usable for practical cost-finding purposes. This is for the simple reason that, after all the work has been done on the veneer as it passes through the plant, there are still very great differences in the intrinsic values according to grades and thickness.

Table 1.—GRADE AND THICKNESS COST ALLOCATION FACTORS FOR VENEER

	1/10	1/8	1/6	3/91
A Sheet	1.62	1.90	2.53	----
B Sheet	1.28	1.50	2.00	----
C Repaired	1.15	1.35	1.80	2.03
C Sheet	1.02	1.20	1.60	1.80
D Sheet	.85	1.00	1.33	1.50
D Cross Band	.76	.90	1.20	1.35
C Cross Band	.85	1.00	1.33	1.50
B Cross Band	1.02	1.20	1.60	1.80
Memo re nominal volume factor	.80	1.00	1.33	1.50

[1]These cost allocation factors will be applied to veneer sheets at the cost to the glue spreader. This means the total cost of veneer basis 3/8 inch after it has accumulated all the costs in the Green End plant, plus all the direct labor for veneer preparation, which includes drying, patching, edge gluing, and so forth.

Table 2.—VENEER COSTS 1,2 PER M, BY GRADE AND THICKNESS

	1/10	1/8	1/6	3/16
A Sheet	$24.031	$28.185	$37.530	$------
B Sheet	18.987	22.251	29.668	------
C Sheet	15.131	17.801	23.734	26.701
D Sheet	12.609	14.834	19.729	22.251
D Cross Band	11.274	13.351	17.801	20.026
C Cross Band	12.609	14.834	19.729	22.251
B Cross Band	15.131	17.801	------	------

[1]These unit costs are the result of applying the cost allocation factors in Table 1.
[2]The costs per M for Veneer shown above were used to compte the cost per M for Panels, shown in Table 3. This is merely a matter of adding together the cost of veneer sheets used in the construction of each panel.

These differences in value are not necessarily related to the differences in cost. As previously pointed out, the cost of a "D" sheet might be as much or more than the cost of an "A" sheet. The differences in values, by grades, are due mostly to what nature did in growing the tree, and this factor completely outweighs differences in plant costs that can be identified in an accurate and practical manner.

The Use of Grade Cost Allocation Factors For Veneer

The solution advocated for this problem is to use fixed-value cost differentials for each grade and thickness of veneer. There are two basic differences, both of which must be recognized. They are 1) differences due to thickness, which is a *quantity* factor, and 2) differences due to grade, which is a *quality* factor. It will not be necessary to explain the quantity factor because it is so commonly used in the industry, particularly in converting production to the 3/8-inch basis. The quality factors will not be so easy to explain, but it will be sufficient to say here that they are based upon the intrinsic value differences of the various grades of veneer. These quality factors, for cost accounting purposes, are as follows speaking of only veneer sheets, 1/8-inch thick:

1/8 inch "A" sheet	1.90
1/8 inch "B" sheet	1.50
1/8 inch "C" sheet	1.20
1/8 inch "D" sheet	1.00
1/8 inch "D" cross bands	.90

These factors are used, together with similar quality factors for other thicknesses, in a simple arithmetical

Table 3.—UNIT COST STATEMENT, PLYWOOD PANELS

Interior Grade—AD		Amount (Proof)	AD-1/4 (5/16)	AD-3/8 (7/16)	AD-1/2 (9/16)	AD-5/8 (11/16)	AD-3/4 (13/16)
Lay-up and pressing		$ 619,724.58	$ 3.493	$ 3.493	$ 6.986	$ 6.986	$ 6.986
Trimming		95,592.07	.626	.720	.814	.908	1.002
Panel patching		312,960.63	2.336	2.453	2.570	2.686	2.803
Panel sanding		232,493.91	1.622	1.784	1.946	2.109	2.271
Whse. and shipping		152,440.68	.764	1.070	1.375	1.681	1.986
TOTAL DIRECT LABOR		1,413,210.67	8.841	9.520	13.691	14.370	15.048
A. Supt. ind. labor	(11.58%)	163,649.79	1.024	1.102	1.585	1.664	1.742
A. P. R. taxes—ins.	(5.44%)	76,878.66	.481	.518	.745	.782	.819
TOTAL LABOR COST		1,653,739.12	10.346	11.140	16.021	16.816	17.609
Total veneer cost		8,701,148.15	47.914	63.045	78.176	91.972	105.922
Total glue cost		620,974.29	3.346	3.681	6.692	7.027	7.361
SUBTOTAL DIRECT COST		10,975,861.56	61.606	77.866	100.889	115.815	130.892
B. Plant overhead	(4.449%)	488,316.08	2.741	3.464	4.488	5.152	5.797
B. Plant fixed charges	(2.947%)	323,458.64	1.815	2.295	2.973	3.413	3.840
SUBTOTAL		11,787,636.28	66.162	83.625	108.350	124.380	139.929
C. Direct selling	(3.97%)	538,408.73	2.994	3.816	4.981	5.659	6.338
C. General overhead	(4.44%)	602,149.82	3.349	4.261	5.571	6.329	7.086
GRAND TOTAL COST		12,928,194.83	72.505	91.696	118.902	136.368	153.357
Selling price (approx. ave.		13,561,932.89	75.42	95.97	125.47	142.54	162.
PROFIT		$ 633,738.06	$ 2.915	$ 4.274	$ 6.568	$ 6.172	$ 8.
Per cent to sales		4.67%	3.87%	4.45%	5.23%	4.33%	5.3
Quantity—Actual S. F.—Panels		124,607.4	57,524.8	14,271.0	15,430.0	7,353.6	30,02

A. Prorated by percent relationship of Indirect Labor to Direct Labor.
B. Prorated by per cent relationship of these plant expenses to subtotal direct cost.
C. Prorated by per cent relationship of these expenses to approximately average selling price.

manner to allocate the total cost of veneer (to the glue spreader) to the veneer produced. After the cost per M is determined for each grade and each thickness of veneer, it is then a simple matter to combine these costs and thus determine the veneer cost for any panel construction. This is the procedure advocated here, and this is the procedure used in making our cost study reports (T., N., B., & S.) for the last two years. A similar study is now being completed for 1956, which will be the third year of experience in the use of these factors.

It is recognized that this cost allocation table is only tentative, and that it is subject to modification after it has been in actual use for a period of time. The table cannot be defended as being strictly accurate, nor as being entirely satisfactory, but it may be said with complete conviction that the basic principles employed are sound and that the accounting procedures used are simple, practical, and workable. There is little doubt that this is a new and revolutionary idea to this industry. If it is a good and a workable idea, then the old traditional method of determining costs, basis 3/8-inch, has been made obsolete. This is for the one very simple reason that the new method provides for determining the cost of every plywood panel produced, so that costs can be compared with selling prices.

At this point it will be important to again emphasize the importance of consistency in the allocation of veneer costs to every grade and thickness of panels produced. By the use of this table of cost allocation factors, the cost relationships of every grade and every thickness of veneer have been standardized. At the same time, the dollars and cents cost per M for each grade and thickness of veneer has been determined. Since the various grades and thicknesses of panels have been standardized, and since these standards are based entirely on the component parts of the panel, which are veneer sheets, it logically follows that each of the various sheets used in a panel has the same intrinsic value wherever it might be used in a panel. For example, if a 1/8-inch "D" sheet has a cost value of $13.00 per M, every panel that contains a "D" sheet will be charged at the rate of $13.00. If the cost of "D" sheet is $13.00, then the cost of an "A" sheet will be 1.90 times $13.00 or $24.70, and every panel that contains an "A" sheet will be charged $24.70 per M.

The Importance of Consistency: The importance of this idea of consistency cannot be over-emphasized. Our cost study reports have disclosed some inconsistencies in pricing that can hardly be described as anything less than gross distortions. Anyone who sees all the various elements of cost consistently applied to all the panels made cannot escape the conclusion that some of the prices are wrong, because they are not consistently related to the costs. Many plywood executives have detected these price distortions merely by applying certain tests of logic and reasonableness, but such methods are, at best, crude and unsatisfactory compared with a systematic and consistent uniform cost-finding method.

The importance of consistency in allocating the cost of veneer to panels has been mentioned specifically, because this is by far the largest element of cost, representing approximately 67 per cent or 2/3 of the grand total cost to make and sell plywood panels. But it will be obvious that all other elements of cost must also be allocated or prorated to panels by the use of standardized rules, and that all these rules must be consistently applied. The cost-accounting system advocated here includes rules for allocating or prorating all elements of cost, including all general overhead and selling expenses.

Rules for Prorating Indirect Costs: It is particularly important to adopt logical and simple methods for prorating indirect costs. The rules adopted may be briefly described as follows: 1) Indirect labor costs are prorated to product lines, and to individual items, by the percentage relationship of these costs to the direct labor, 2) plant overhead costs are prorated to product lines or grades, and to individual items, by the percentage relationship of these expenses to the subtotal of direct costs, and 3) General overhead and selling expenses are prorated to product lines or grades, and to individual items, by the percentage relationship of these expenses to the sales value of the items.

Illustrative Cost Computations: These illustrations (tables 1, 2, 3, and 4) are necessarily very brief, and are included as subsidiary schedules solely for the purpose of giving a more comprehensive understanding of the fundamental principles that have been presented.

The Importance of A Grade Yield Index:

Thus far, it has been emphasized

Table 4.—RELATING COST OF LOGS TO COST OF VENEER

BY COMPUTING THE COST OF VENEER BY GRADE AND THICKNESS IN A STANDARDIZED MANNER, IT IS POSSIBLE TO RELATE THE COST OF VENEER TO A PARTICULAR TYPE OR GRADE OF LOGS AND DOING THIS WILL ENABLE THE PLYWOOD EXECUTIVE TO DO A MORE INTELLIGENT JOB OF BUYING LOGS. WITHOUT THIS COST INFORMATION, LOG BUYING IS A HAPHAZARD, UNSCIENTIFIC OPERATION WHICH RESULTS IN MILLIONS OF DOLLARS OF EXCESSIVE COSTS. WHAT THE LOGS ARE REALLY WORTH DEPENDS UPON WHAT IS IN THEM AND A SCIENTIFIC COST ACCOUNTING APPROACH WILL SUPPLY THE CORRECT ANSWER TO THIS EXTREMELY IMPORTANT QUESTION. THE FORMULA FOR COMPUTING THE COST OF VENEER BY GRADES IS ILLUSTRATED BELOW, USING ASSUMPTIONS WITH RESPECT TO (1) THE PRICE OF LOGS, (2) RECOVERY YIELD, (3) GRADE YIELD, AND (4) VENEER MANUFACTURING COSTS.

COST OF LOGS - PER M BOARD FEET	$38.00 PER M BOARD FEET
DIVIDE BY RECOVERY YIELD EXPERIENCE, WHICH IS 2.20 TO DETERMINE THE COST PER M FOR PLYWOOD, WHICH IS	$40.00 PER M BASIS 3/8"
ADD GREEN END COST EXPERIENCE	8.25 PER M BASIS 3/8"
ADD VENEER PREPARATION COST EXPERIENCE	8.75 PER M BASIS 3/8"
TOTAL COST - TO GLUE SPREADER	$ [illegible] PER M BASIS 3/8"
DIVIDE BY 3 TO CONVERT COST TO BASIS 1/8"	$19.00 PER M BASIS 1/8"
DIVIDE BY GRADE YIELD EXPERIENCE OF 118.0, IN ORDER TO CONVERT THE COST BASIS 1/8" TO THE COMMON DENOMINATOR ITEM - 1/8" SHEET - "D" GRADE	$16.00 PER M - 1/8" D SHEET

IT WILL BE FURTHER ASSUMED THAT THE COMPANY IS WELL AWARE OF THE FACT THAT ITS FINAL TOTAL COST OF VENEER MUST NOT EXCEED $14.00 PER M FOR 1/8" "D" VENEER. IN ORDER TO BE ABLE TO MAKE AND SELL PLYWOOD AT A PROFIT. THIS ASSUMPTION HAVING BEEN MADE, IT IS NOW POSSIBLE TO REVERSE THE ORDER OF THE COST COMPUTATIONS SHOWN ABOVE STARTING WITH THE PREDETERMINED MAXIMUM COST OF VENEER ($14.00) AND WORKING BACKWARD TO THE VALUE OF THE LOGS. THIS IS ILLUSTRATED AS FOLLOWS

PREDETERMINED MAXIMUM COST OF VENEER FOR 1/8" D SHEET	$14.00 PER M - 1/8" D SHEET
MULTIPLY BY THE EXPERIENCE DETERMINED GRADE YIELD OF 118.0 TO CONVERT BACK TO 1/8" VENEER, WITHOUT REGARD TO GRADE; THE RESULT OF THIS COMPUTATION BEING	$16.52 PER M BASIS 1/8"
MULTIPLY BY 3 TO DETERMINE COST - BASIS 3/8" - THE RESULT OF THIS COMPUTATION BEING	$49.50 PER M BASIS 3/8"
LESS THE COST OF "GREEN END" AND "VENEER PREPARATION," BASED ON EXPERIENCE	[illegible] PER M BASIS 3/8"
BALANCE - VALUE OF VENEER IN LOGS BASIS 3/8"	$32.56 PER M BASIS 3/8"
MULTIPLY BY RECOVERY YIELD DETERMINED BY EXPERIENCE - 2.20 - TO CONVERT TO THE VALUE OF LOGS IN TERMS OF BOARD FEET - THE RESULT OF THIS COMPUTATION BEING	$71.63 PER M BOARD FT.

IN OTHER WORDS, HAVING PREDETERMINED THE RECOVERY YIELD, THE GRADE YIELD, AND THE VENEER PROCESSING COSTS BASIS 3/8" - IT IS THEN POSSIBLE TO DETERMINE HOW MUCH CAN BE PAID FOR THE LOGS. IN THIS CASE, THE LOGS ARE WORTH $71.63 PER M BOARD FEET. IF THESE IMPORTANT COST FACTORS (RECOVERY YIELD, GRADE YIELD, PROCESSING COSTS) CAN BE DETERMINED, OR ASSUMED WITH ANY DEGREE OF ACCURACY WITH RESPECT TO ANY GRADE, OR CLASS, OR CATEGORY OF LOGS, THEN THE VALUE OF THE LOG CAN BE RELIABLY COMPUTED

that, by using standardized cost-allocation factors for determining veneer costs by grade and thickness, it is possible to determine the grand total cost to make and sell plywood panels by grade and thickness. There is another extremely important and closely related advantage that comes from using these veneer cost-allocation factors. This is a cost index, which has been designated as "grade yield". When the total footage, basis 1/8 inch, (determined by using quantitative factors only), is compared with the total converted footage, basis 1/8 inch "D" sheet (using both quantity and quality factors) we are able to create this important cost index, which expresses the production yield of veneer in terms of *quality*. Everyone knows the meaning of the "yield" of veneer from logs, which expresses the relationship of veneer produced, basis 3/8 inch, from the board feet of logs used; this is strictly a quantitative index because it completely ignores the quality of veneer produced. This quantitative recovery yield is normally about 2.2, more or less. The grade yield is equally important, if not more so, because it expresses in one index figure the results achieved in terms of the *quality of veneer produced*. The higher the grade yield the lower the cost of veneer. Conversely, the lower the grade yield the higher the cost of veneer. For example, if the average normal grade yield for a particular company were 120.0, an increase of 12 points in the grade yield index (all other costs remaining the same) will result in a decrease of 10 per cent in the cost of veneer. When the full meaning and significance of this index is understood by the plywood executive, it will be extremely important to him because grade yield is, to a considerable extent, a controllable cost factor.

The Veneer Cost Formula

The controllability of grade yield is, of course, closely related to other cost factors, particularly the price of logs and the cost of processing veneer from these logs. All these cost factors are inter-related, but these relationships cannot be fully understood, nor evaluated, unless and until the grade yield factor has been computed. These three factors which result in the ultimate cost of veneer can be reduced to a simple arithmetical formula, expressed somewhat as follows:

Step No. 1—Divide the cost of logs per M board feet by the quantitative yield factor; this determines the cost of veneer per M for logs only, basis 3/8 inch.

Step No. 2—Add to the cost per M basis 3/8 inch for logs, the cost of the Green End Department. Also, add the cost basis 3/8 inch for all direct and indirect labor costs involved in preparing the veneer for use in a panel, such as drying, edge gluing, patching and so forth. The result of adding all these veneer processing costs to the cost of the logs used will be the cost of veneer basis 3/8 inch to the glue spreader, at which point the veneer has been identified by grade and is ready to be used in a panel.

Step No. 3—Divide the cost per M basis 3/8 inch (from Step No. 2) by the grade yield factor. The result of this computation will be the cost per M basis 3/8 inch "D" sheet. Divide this result by 3 to determine the cost of a 1/8 inch "D" sheet. This is the final unit cost of veneer in terms of an index item, and it is the final answer that results from the use of this cost formula. This cost of a 1/8-inch "D" sheet might be $12.00, or $16.00, or any place in between. Cost studies have shown cost ranges or differences of at least that much (that is, $4.00 per M for a 1/8-inch "D" sheet). Present market conditions make a 1/8-inch "D" sheet worth no more than about $12.00 to $13.00 per M.

After the cost of a 1/8-inch "D" sheet has been determined, it is a very simple arithmetical computation to prepare a table of costs for every other grade and thickness of veneer. This is done simply by multiplying the cost of the 1/8-inch sheet ($12.00 for example) by the proper cost allocation factor. This computation will require about ten minutes with a calculator. With the cost of veneer by grade and thickness determined, the final step is simply to combine or add the cost of the veneer used in each panel construction. The most important part of the unit cost statement for plywood panels, by grade and thickness, is then complete.

Relating the Cost of Veneer to the Value of Logs

A three-step formula for determining the cost of veneer by grade and thickness has been described. By reversing these computations, it is possible to begin with the cost value of veneer basis 1/8-inch "D" sheet, and work backwards to the cost value of the logs. If it is assumed, for example, that the objective is a maximum cost of $14.00 per M basis, 1/8-inch "D" sheet, and if it is further assumed that the recovery yield and grade yield are known, and that the Green End and veneer processing costs are known, it is then possible to compute the maximum price that can be paid for logs in order to achieve a minimum cost of $14.00 for veneer basis 1/8-inch "D" sheet.

On the basis of three years of experience, it is a considered opinion that such a formula is absolutely necessary if the plywood manufacturer is to learn how to properly evaluate the logs he buys. It may be said that the present method of buying logs, by grades, is unscientific and obsolete. It is a "Rule-of thumb" method that assumes certain differences in the value of logs by grades.

These differences may have been reasonably correct at some time in the past, but they are now unrealistic. By this is meant that they do not reflect the real differences in value. The real differences in the value of logs can be determined by a standardized system of evaluating the quantity and quality of veneer that is actually in, and produced from, these logs, disregarding the traditional method of grading, except perhaps that these grades might still be used merely for the purpose of identifying them as to quality categories. It may also be predicted that during the next five to ten years, this industry must and will evolve a more scientific and realistic method of buying logs; and that the basic cost principles discussed here will become a part of the new and more scientific approach to the problem of valuing logs.

Importance of Proper Utilization of Veneer Grades

A discussion of the important factor of grade yield would be incomplete if another phase of this subject were not mentioned. This is the improper utilization of veneer grades in the construction of plywood panels, or "downgrading." For example, a "C" grade of veneer has a definitely higher intrinsic value than a "D" grade of the same thickness. There is always a price premium in a standard panel construction that calls for a "C" sheet instead of a "D" sheet. Therefore, if a "C" sheet is substituted for a "D" sheet, this premium value will be lost. Downgrading in this manner is a very costly mistake. There is reason to believe that many millions of dollars are lost every year by the plywood industry because of the improper utilization of the veneers actually recovered from logs. Sometimes it is done because of carelessness, or lack of cost consciousness; sometimes it is done deliberately because the plant does not have a balanced supply of the necessary grades of veneer. Regardless of the reason, no plywood manufacturer can afford this costly mistake, and it probably would rarely be done if the management knew how really costly the mistakes can be. When downgrading occurs, the effect is, of course, to lower the grade yield; and in some instances a low grade yield may be due very

l gely to the improper utilization of v neer grades. When veneer costs are d termined by grades, by the use of s ndard grade cost allocation factors, i is possible to compute the excessive c st of downgrading. For a simple e mple, the difference in cost between a 1/8-inch "C" sheet and a 1/8-inch "B" sheet is about $3.00 per M; this w uld be the excessive cost if only o e "C" sheet were substituted for a "B" sheet in a given panel.

Discussion

John Syme: Do you feel that the C st Allocating Factors are accurate?

Mr. Mayhew: They probably are n t absolutely accurate, but three years o experience has provided no obvious r ason for changing them.

Anon.: How were your Cost Allocating Factors derived?

Mr. Mayhew: They were based upon the intrinsic values—based on what the user has been willing to pay.

Anon.: If the best use were made of veneer grades, do you think that this would be reflected in a narrower price range?

Mr. Mayhew: Not likely. "A"-grade is a luxury item and is sold as such. I would like to add here that, if the price structure changed radically, it might be necessary to change the Cost Allocating Factors. During the 20 years that the system has been used in the peach preserving industry, however, it has not been found necessary to change the C.A. Factors for that industry, and in the cases of 15 different fruit and vegetable products, it has been necessary to change the C.A. Factors only twice.

Anon.: When assembling individual panel costs, are they based on individual panels or on the total production of that particular panel construction?

Mr. Mayhew: On the total production of that panel.

Anon.: How much work was necessary to set up the system?

Mr. Mayhew: We studied each of 10 plywood plants for one year, and the consolidated the results of these studies.

Anon.: What assumptions were made in calculating these C.A. Factors?

Mr. Mayhew: These factors are merely an arithmetical tool for the purpose of making this allocation.

H. Lindholm: Do you feel that your system is applicable for internal cost-control purposes of a company?

Mr. Mayhew: The system was designed for industry-wide cost accounting, but a more flexible system would be preferable for the company that wants to keep very detailed costs for internal control.

Anon.: Starting with the selling price or profit for each grade of plywood, can your system be used to calculate what you can afford to pay for each grade of logs?

Mr. Mayhew: No, the assumption there is wrong. Our system is not based on the selling price. It is difficult to illustrate here, but you will see by the example in the printed paper.

The Fire Performance of Timber[1]

H. E. THOMPSON

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Fire performance depends on rate of loss of strength, rather than on combustibility. For this reason, large timbers are superior to structural metals, which lose strength rapidly at high temperatures. This better time factor lessens the danger of collapse on occupants, contents, and fire fighters.

TIMBER IS OFTEN REGARDED as a hazard in buildings, even after centuries of safe usage in structures of all types. Actual fire experience does not support this mistaken idea, which is based simply on the knowledge that wood will burn. Yes, wood will burn — split it up into kindling or shave it into excelsior and the kitchen fire can be started quite easily. But try some other materials in finely divided form. Structural steel is non-combustible; light a match to steel wool and blow on it to see how steel too will burn. Aluminum sheets are non-combustible, but aluminum dust burns so rapidly that it can be exploded. In discussing building materials, the size of the construction assemblies and the conditions of their use are very important in how they perform in a fire.

Actually, in the form of building materials, wood is difficult to ignite, burns slowly, retains its shape, and supports the structure for some time after a fire starts. Because of these features, timber usually performs better in a fire than many non-combustible materials, because—it provides more time for evacuating the occupants and extinguishing the fire. In short, fire performance embraces more than the simple yardstick of material combustibility.

Fireproof or Fire Safe Buildings?

No building is fire proof. All can be damaged by intense heat. Fire endurance of building materials is merely a matter of time and temperatures. After two years of research on fire safety by the Canadian Institute of Timber Construction, two conclusions are apparent. These are:

(1) That the role of building materials in fire safety has been magnified out of all proportion to its true importance.
(2) That the essential requirements for real fire safety in a timber building are equally necessary in other types of construction.

The basic question is what are we trying to protect in a building—the occupants—the business operations—the structure—or all three? To put these objectives into proper perspective, the heat vulnerability of people and materials must be properly understood and appropriate protective measures applied.

Life Safety

First, take a look at personnel safety. In considering the life safety of the occupants of a building, the most important single factor in case of fire is prompt detection of the fire. The truth of this statement is borne out by Canadian fire casualty records, which show that over 80 per cent of fire fatalities occur in residential properties, mostly during sleeping hours in the winter months. If the fire is not detected promptly, the occupants can be in

[1] Presented at the Spring Meeting of the FPRS Eastern Canadian Section, held March 7-8, 1957, Montreal, Quebec, Canada.

The Author: Hugh Thompson graduated in 1948 from the University of Toronto in chemical engineering. He has been in the fire protection field since that time, the last three years with the CITC.

Fig. 1.—A graphic portrayal of the value of timber in an intense fire.—AITC photo

danger in a matter of minutes. Temperatures in the order of 300° F. can be deadly within 10 minutes, and temperatures of even 200° F. would weaken a person's ability to leave a building, especially if the usual smoke and toxic gases were present.

Most building materials, including timber, would not even be ignited at these temperatures, which are critical for human survival. The principal danger to life, therefore, arises from the gases generated by building contents and equipment in the initial stage of the fire. Adequate alarm and exit facilities are the main lines of defence against this hazard, where every minute is of vital importance.

Structural fire endurance has little bearing on life safety, provided exit facilities of a high standard are available. Fire damage to buildings does not reach serious proportions until some time after the chances of human survival are practically zero.

Origin of Fires

Nearly all fires originate in the contents and not in the structure. This is because the contents are more susceptible to ignition and heat damage. The explanation is simple. To make any object burn, it must first be vaporized. Some combustible contents of buildings occur in liquid or gaseous states, and these materials constitute the greatest danger, because they can often be ignited by a spark at ordinary room temperatures.

Most building contents, however, and all building materials are present in solid form and require varying amounts of heat to convert them to gases that will ignite and support combustion. The amount of heat necessary to convert these solid materials into flammable gases will depend to a large degree on the shape and size of the object attacked by the heat. Since the contents are present in less compact forms, only small amounts of heat are needed for ignition. Consequently, most fires start within the contents from the many common sources of ignition involved in modern living.

In general, fires must start in tinder, in which the ratio of exposed surface area to mass of material is sufficiently high for self-supporting combustion, even when moderate heat is applied over a very small area. A more precise definition of tinder is that it has a specific surface of more than 20 square centimeters per gram of combustible material.

Much of the normal contents of a building fall into this tinder class, but wood in dimensions ordinarily associated with building materials has a specific surface that is only a very small fraction of that of tinder. Common experience will support the view that wood is not a suitable material for starting fires until chopped into tinder size.

Fire Spread

The mere fact that wood is combustible does not necessarily mean that it will spread fire. Completely burning a one-pound piece of resin-free wood releases 8,000 to 9,000 BTU; 75 to 80 per cent of this heat is lost to the surrounding air, leaving only about 1800 BTU to dry out and heat more wood to the ignition point. On the other hand, it takes about 1300 BTU to heat one pound of oven-dry wood and the necessary 10 pounds (133 cubic feet) of air from room temperature to the ignition point. With moisture present in the wood, it will require an additional 200 or 300 BTU's to break the bond between water and wood and produce steam, which absorbs further heat as its temperature is raised. If the amount of residual heat available to ignite more wood is less than this initial input, the flame goes out.

Extensive tests at the Factory Mutual Laboratories (Reports 11760 and 11975) on wood paneling on walls and ceilings showed that, when the igniting fire of tinder simulating the contents of a room had used up its fuel, the wood paneling fires ceased flaming.

It was also significant in these tests that the addition of 2½ pounds of fuel to the igniting fire in the test room produced a greater room temperature increase than did the presence of 293 square feet (about 600 pounds) of paneling on the walls and ceiling. The persistence of flame spread on smooth wood surfaces of buildings depends principally on the heat from the burning contents.

On this point, N. J. Thompson, Director of Factory Mutual Laboratories (N.F.P.A. Quarterly, page , July 1952) stated: ". . . . . we found in our war-time research work that active flaming combustion on smooth wood ceilings would not persist, if the temperature of the air adjacent to the wood surface was prevented from rising substantially above 1000° F, although glowing combustion might still persist".

Rapid fire spread is associated not so much with the structure as with the contents or with interior linings of material with a higher specific surface than wood. In a stairwell or exit corridor without any contents present, interior finish is of first importance. In any room, however, when the ease of ignition, rate of burning, and location of contents with respect to ignition sources are considered, it is evident that the role of the contents is far more critical than the type of lining or interior finish. Until the room interior finish approaches the fire characteristics of the contents, fire spread will depend primarily on the contents.

Contents vs Building

The term "fire load" is used to describe the number of BTU's that could be liberated per square foot of floor area by the combustion of the contents of a building and any combustible parts of the building itself. It is determined simply by multiplying the weight of all combustible materials by their caloric values and dividing the product by the floor area under consideration. This fire load concept thus provides a useful yardstick for measur

ing the relative heat contribution of timber construction and building contents.

From data obtained from a number of sources, it has been found that the fire load of residential buildings, hotels, hospitals, schools, offices, and similar occupancies does not often exceed 80,000 BTU's per square foot. This is commonly designated as a "low" fire load.

In a building with a wood roof deck 1 inch thick, the amount of wood in the roof would be about two pounds per square foot. At 8,000 BTU's per pound, if the entire roof deck were consumed in a fire, this would only be equivalent to a fraction of what has been defined as a "low fire load". At the other end of the scale, the fire loads of normal contents range from 10 to 40 pounds per square foot, and a very high fire load such as may occur in some warehouses might be as high as 400 to 500 pounds per square foot. In such cases, the timber roof would be adding a neglibible amount of the potential fuel, even if it were entirely incinerated.

In actual fires, however, all the roof deck is not consumed, and depth of charring normally varies from ¼ to ½ inch from the exposed surface. This indicates that the actual fire load contribution of a wood roof deck is more in the order of ½ to one pound per square foot, regardless of the roof thickness. In fact, as timber increases in thickness, its fire endurance improves. Heavy timber is a practical example of this improved fire resistance with increased timber sizes, although the "theoretical" fire load is greater.

It is the belief of many fire authorities that the pounds of combustibles in the structure is not the critical fire factor. The rate of burning of the contents, the heat resistance of structural members and the facilities for fire fighting are considered far more important.

Damage from Collapse

Actually, other forms of damage can be more costly than flaming in a fire. Often, the collapse of the framework will do more damage than the fire. This was a vital factor in the complete destruction of the 34-acre building of General Motors at Livonia in 1953. When the steel framework began to groan and sag over the heads of firemen, they naturally retreated to the outside, and from there futilely threw water a distance of 100 feet into a 34-acre blaze.

The Livonia plant fire shattered the "non-combustible" myth. It was a non-combustible building with "non-combustible" machinery that used "non-combustible" materials to produce a "non-combustible" product. Yet, Livonia is the largest single fire loss on record. Livonia also brought home the lesson that damage from premature building collapse can be a lot more serious than having combustible structural framing.

Fire Fighting Critical

The speed and effectiveness with which a fire is attacked will govern the extent of damage to both contents and structure. Whenever the fire department receives prompt notification, the fire can usually be controlled with small property loss. Of all the fires reported in Canada since World War II, only about three out of every thousand exceeded $50,000 damages. This emphasizes the importance of prompt detection and fire fighting in minimizing damage.

These occasional large losses can be traced to several contributing factors combining at one time to overpower the fire defences of the property. Delayed detection, inadequate water supplies for extinguishing purposes, high winds, structural deficiencies, and human errors in fire fighting all play their part.

As far as structural deficiencies are concerned, one of the principal defects is the presence of open vertical shafts and stairwells, which allow rapid spread of hot gases to upper stories. Similarly, openings in partitions and walls contribute greatly to rapid horizontal fire spread and should be avoided or protected. At best, the structure can only help to confine a fire to a given area, and for this function to be effective, all openings must be protected, regardless of the type of construction.

A building material can neither detect nor extinguish a fire, however. If damage to both contents and the structure are to be kept to a minimum, automatic alarms and extinguishing equipment are the answers. Automatic sprinklers provide the best all-round protection available for this purpose. Unfortunately, most properties are not sprinklered and buildings become structural furnaces.

The Structural Furnace

When the contents of an unsprinklered building are on fire, there is a furnace effect with the intense heat attacking the structure. This heat can only be estimated, but in laboratory test furnaces, temperatures in the order of 1500° F. are reached within half an hour, and higher temperatures follow. This is very much beyond the range of survival for either the occupants or contents in the immediate vicinity.

Fig. 2.—Although this timber structure burned, it retained its strength so that firemen could extinguish the fire.—AITC photo

Fig. 3.—The collapse of this masonry building was attributed to rapid dimensional changes caused by the heat.—AITC photo

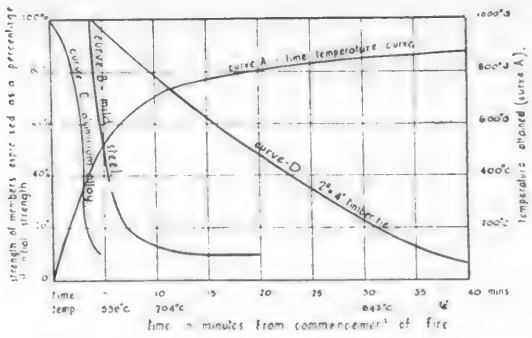

curve A - time temperature curve
curve-D
2"x4" timber tie
Time in minutes from commencement of fire
Temperature attained (curve A).

Fig. 4.—Strength of steel, aluminum, and timber in relation to the standard fire test. AITC data.

Ordinarily, real fires may not reach these proportions, because of the cooling action of fire department hose streams and venting operations. Fire departments vent the heat as soon as possible by breaking windows and opening holes in the roof.

Incidentally, one built-in feature of wood roofs is the fact that fire fighters can easily break open the roof deck. In this way, the hot gases and smoke can be vented to the atmosphere, and fire fighting carried on inside the building at close range more effectively.

The important point about structural fire resistance is not whether the materials burn when exposed to intense heat, but how long they can stay intact while vital extinguishing operations are being carried out.

Building Material Fire Resistance

No building material is immune to fire damage. Each has its own peculiar properties when exposed to conditions of severe heat. However, all building materials perform better as dimensional sizes increase and exposed surface areas proportionately decrease. A beam will last longer than a joist, a column longer than a stud, and so on.

Wood's high insulating quality provides built-in fire resistance. Timber burns slowly, and forms char on the surface. The unburned wood retains its strength and will remain in position for some time during a fire. Also, because timber does not expand or contract appreciably in a fire, the cross-sectional area must be reduced considerably before failure occurs. Wood members 6 by 6 and larger can be exposed to a prolonged fire and still support their load. With smaller members, failure will be gradual as cross-sectional areas are slowly reduced in size. In either case, fire departments can operate safely for some time in a timber building.

Metal building materials are not combustible, but they are subject to collapse in the early stages of a fire. As temperatures rise, steel and aluminum lose their structural strength rapidly. Steel starts to weaken between 600 and 800° F., and aluminum between 200 and 600° F. It does not take long to reach these moderate temperatures in a fire. In addition, both these metals readily expand under the influence of heat. Often this expansion pulls the building walls, floors, and roof down without warning. For this reason, fire departments are handicapped by the threat of sudden building collapse and prefer to fight the fire from outside.

Concrete is damaged by heat, and spalls and cracks. Its fire strength depends on a suitable aggregate, a good-quality cement, proper proportioning, and care in mixing. Of all these factors, the type of aggregate is most critical.

Other examples could be cited to illustrate the point that all materials are subject to fire damage. However, the fire performance of timber is the main topic of interest.

For practical purposes, the significant features of timber construction can be summarized as follows:

(1) Timber does burn, but retains its strength and shape for some time in a fire. For this reason, evacuation and firefighting operations can be carried out without fear of sudden building collapse.

(2) Like other materials, timber's fire resistance increases as the structural size gets bigger and exposed areas decrease.

(3) Glued laminated structural elements, such as arches, beams, and columns, have a fire performance comparable to solid wood members of equivalent size.

(4) Timber has more fire endurance than unprotected "noncombustible" metallic building materials of similar structural use.

(5) Where necessary, the fire performance of wood can be effectively improved by pressure treatment with fire retardant chemicals, which delay ignition and reduce surface flame spread.

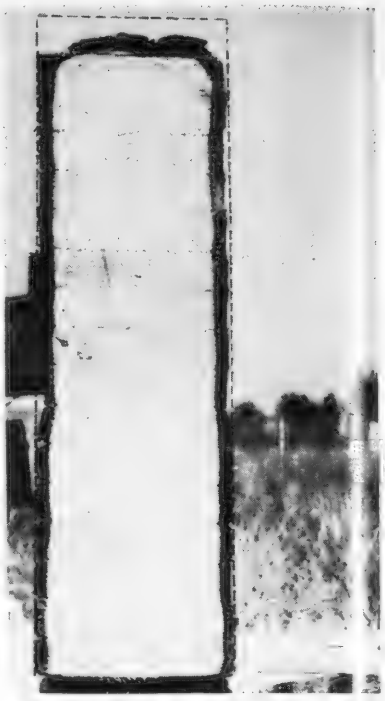


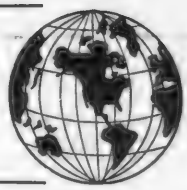
Fig. 5.—Glued laminated beam, 9 by 27⅝ inches, subjected to open fire test for one hour, at an average temperature of 1270° F. Dotted lines indicate the original size. The remaining sound, uncharred section is 7¼ by 26 inches. The beam is capable of continuing in service with a safety factor of more than 2 to 1.

Perspective Needed for Real Fire Safety

Far from being a fire hazard, timber compares favorably with other building materials of equivalent cost. At more expense, more fire resistance can be obtained by using heavier timbers, but for what purpose—to protect the occupants,—the contents—the business—or the structure?

Experience indicates that excessive emphasis on the structure produces a false sense of security in the so-called "fireproof" building. Without adequate fire prevention, exits, alarms and extinguishing facilities, however, no building is fire safe, let alone "fireproof". These four basic requirements apply equally to all types of construction. The safety of the occupants, the contents, the business, and the structure must be kept in proper perspective for sound fire protection practice.

Around the World in Forest Products Research and Development



Forest Products in the Post-War Decade

Output of timber from the world's forests showed steady expansion in the ten-year period 1946–1955, according to a new publication entitled "World Forest Products Statistics, a Ten-Year Summary", recently published by the Food and Agriculture Organization of the United Nations (FAO).

Except for a slight decline between the years 1951 and 1953, the total timber harvest increased throughout the post-war decade, with a particularly rapid rate of growth in the USSR, the Pacific area, and Asia. The publication, compiled in collaboration with ECE, contains figures on timber removals, production of forest products, and world trade from more than 150 countries and territories.

According to reported figures, the world output of fuelwood declined from 52 per cent of total roundwood removals in 1946 to 41 per cent in 1955. The proportion of industrial wood increased and the coniferous species provided more than three-fourths of the industrial wood supply in the world. Regions with broad-leaved species predominating were South America, Africa, Asia and the Pacific area.

Sawlogs, veneer logs, and logs for sleepers were the largest category of industrial wood, followed by the pulpwood pitprops group and other wood for chemicals, poles, piling and posts. Among the processed forest products, sawnwood remained the most important both in quantity and value. North America produced the largest volume of sawnwood throughout the decade. The most rapid rate of growth in output was reported from the USSR.

World sawnwood production increased from 186 million cubic meters in 1946 to more than 295 million cubic meters at the end of the period. The leading sawnwood exporting country was Canada, followed by Sweden and Finland. Toward the end of the decade, Austria emerged as the world's fourth-largest sawnwood exporter.

Plywood expanded in production from just over three million cubic meters at the beginning of the period to almost 11 million cubic meters at the end. The leading plywood-producing countries in 1955 were the United States, the Soviet Union, Canada, Japan, and the Federal Republic of Germany. The most rapid 10-year growth in output was reported from Asia (mostly Japan), followed by Central America (Mexico). The number of countries reporting plywood production increased from 37 in 1946 to 57 in 1955.

The largest plywood exporter throughout the decade was Finland, with 42 per cent of total world export volume in 1946, 48 per cent in 1950, and 32 per cent in 1955. The growth in export volume was especially large in Japan and other countries, with important increases in plywood exports reported for the Federal Republic of Germany, France, Italy, Rumania, Surinam, French Equatorial Africa, and Nigeria.

The woodpulp industry was dominated by North America, Finland, Norway, and Sweden. North America produced 70 per cent of the total world volume in 1946, with a decline to 60 per cent in 1955. The three North European countries accounted for 20 per cent of world output in 1946 and 17 per cent in 1955. Rapidly increasing woodpulp production was reported from Africa, Asia, and the Pacific area.

During the decade, Europe changed from a net exporter of woodpulp to a net importer, whereas North America showed the opposite development. According to FAO reports, the mechanical class of woodpulp constituted approximately one-third of all woodpulp production, with a slight downward trend during the last four years of the period. For pulp from fibers other than wood, the leading producing region has been Europe, with about 45 per cent of world output.

In newsprint production, North America and Europe continued to lead all other regions, but the rate of development in the Pacific area and in Asia was outstanding, FAO reports. Canada was the leading newsprint-exporting country, with 79 per cent of total world shipments in 1955. The second-largest shipper was Finland.

Throughout the ten-year period, the region producing the largest volume of paper other than newsprint was North America. The most rapid growth in production, however, was reported from Asia and the USSR. The main exporting countries at the end of the period were Sweden, Finland, United States, Norway, and Austria. The first two of these countries accounted for more than 45 per cent of world shipments in 1955.

About 91 per cent of the 1955 production of paperboard came from North America and Europe, who were the leading producers throughout the decade. The fastest rate of growth in production was reported from Asia, followed by the USSR, but largest increase in volume of output, 5.2 million tons, was in North America. The second-largest increase in volume was the 2.4 million tons reported from Europe. The major exporting countries for paperboard at the end of the decade were the United States, Netherlands (strawboard), and Finland. Fast-growing export volumes were reported from Austria and Japan.

Fiberboard had been produced mostly in North America and Europe, but substantial increases in output were reported from the USSR and the Pacific area. The volume of production in 1955 was highest in the United States, nearly 1.5 million tons, followed by Sweden with 424,000 tons. At the end of the period, 52 per cent of world fiberboard production was classified as "compressed" and 48 per cent as "non-compressed".

The publication supplying these statistics contains 51 tables, 12 charts, and text in three languages; English, French, and Spanish. Cost is $3.00 or the equivalent in other currencies.

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Three Models. Complete Range of Sizes. Lowest-cost installation. Prefabricated, one-piece panels. Exclusive triple-draft. Sizing engineers available to you.

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The American Woodworking Machinery and Equipment Show
Winston Salem, N. C.
MAY 13–17
MILL EQUIPMENT INC.
5219 First Ave. South Seattle 8, Wash.

Abstracts From Current World Literature

Preservation

Hughes, R. L. The application of mould-proofing agents to paper and board. World's Paper Trade Rev. 148, no. 7:506, 508, 510 (Aug. 15, 1957) *cf.* B.I.P.C. 27: 1146.

The fungusproofing of paper and board is a problem of searching for new markets. The increase in cost will probably be offset by an increased demand for the treated products. Factors determining the probability of microbial growth on paper include the nature of the fibrous material, the additives, coating agents, materials with which paper is in contact, and the ambient temperature and moisture to which the paper is exposed. To grow, micro-organisms need a source of food, a suitable temperature, enough moisture and oxygen and, in some instances, light. Below 97% R.H., bacterial and algal growth stops; hence the proofing problems are mostly concerned with the control of fungi. All control methods attempt to withhold micro-nutrients from the organisms either by mechanical barriers or by the use of toxic substances. To the first category belong the bitumenized and wax-coated papers; smooth surfaces obtained by calendering also help by making the product less likely to trap dirt. To be adequate, chemical toxicants must give complete protection, be unimpaired by the manufacturing process, cause no printing and converting trouble, and must not impair the physical characteristics (color, odor, etc.) of paper. Toxic agents may be added to the beater or to the coating material. The applications of some common fungicides are discussed. [Bul. Pap. Chem. V. 28, No. 2]

Machining

Franz, Norman Charles. An analysis of the wood-cutting process. Univ. of Mich.). Univ. Microfilms (Ann Arbor, Mich.), Publ. No. 21,178: 187 p.; Dissertation Abstr. 17, no. 6: 1278–9 (June, 1957).

An analysis of the wood-cutting process is accomplished by observational studies of the chip during formation and by simultaneous determination of attending forces on the cutting tool, together with a determination of the mechanical properties of the material being machined. Principal variables include species, moisture content, cutting angle, and chip thickness. An equation is suggested which determines chip formation as a function of friction, cutting geometry, and mechanical wood properties. [Bul. Pap. Chem. V. 28, No. 1]

Wood Structure

Shellhorn, Samuel, and Hoshaw, Robert W. Rapid method for preparing wood sections. Stain Technol. 32, no. 4: 157–60 (July, 1957).

The preparation of wood sections for microscopic study normally requires considerable time and the employment of expensive equipment. With the use of an ordinary carpenter's plane and a softwood embedding block, sections ready for staining can be prepared in a matter of minutes. Common stains such as safranin, fast green, and orange G can be used to make permanent slides for the comparative interpretation of wood structure. Several desert woods were sectioned and stained, including ironwood, creosote bush, mesquite, and Arizona ash. [Bul. Pap. Chem. V. 28, No. 1]

Gluing

McFall, Joe B. Improved mounting means for glue spreading rollers. U. S. patent 2,775,953. Filed June 13, 1952. Issued Jan. 1, 1957. 17 claims. [Cl. 118–227] M. 792.

The thickness of the film of glue applied by the apparatus is varied by adjusting the relative positions of the glue-spreading and doctor rolls. To this end, the mounting of each roll includes a pair of cylinders, each having a pneumatically movable piston and shaft. Adjustment of the air pressure thereby moves the rolls as desired. [Bul. Pap. Chem. V. 28, No. 2]

Paints

Werthan Sidney. Combating the blistering of paint. Official Digest, Nat'l Assn. of Housing and Redevelopment Officials, 1313 E. 60th St., Chicago 37, Ill. March 1957, 8 pages.

Article is taken from a group of papers by the Zinc Pigment Committee of American Zinc Institute of which the author is a member. It discusses the protection of new wood, detailing tests made by AZI to establish the performance of a standard 2-coat system as to blister resistance. It also prescribes procedures for repainting on existing buildings where blistering has occurred. [BRI Abstracts, Dec. 1957]

Plastics

Platzker, Joseph. Plastic building products. 116 John St., New York 38, N. Y. 1957. 8 pages.

Some 112 plastic building products approved by the New York City Board of Standards and Appeals since January 1947 are classified in this research study. The author, a member of ASTM and ICBOCA and former N. Y. Commissioner of Housing and Building, also points out the obstacles to acceptance of structural plastic panels, plastic pipe, etc. in the New York area at the present time. [BRI Abstracts, Dec. 1957]

Lignin

Sarkanen, Kyosti, and Schuerch, Conrad. Lignin structure. XI. A quantitative study of the alcoholysis of lignin. J. Am. Chem. Soc. 79, no. 15:4203–9 (Aug. 5, 1957); *cf.* B.I.P.C. 14:824.

The results of a study on the re-ethanolysis of ether-insoluble ethanol lignins isolated from sprucewood are reported. The formation of monomeric products by re-ethanolysis from analogous preparations has been shown to be less than 3%; the results therefore describe reactions which occur on that portion of lignin which remains almost exclusively as a complex mixture of low polymers. The following changes occur on re-ethanolysis: a maximum of 42–57% of the guaiacylpropane units become ethoxylated by a rapid reaction which seems to be independent of the liberation of phenolic groups. New phenolic hydroxyl and α-carbonyl groups are generated by a slower cleavage reaction in nearly 1:1 molar ratio. The concurrent decrease in molecular weight indicates that the liberation of the phenolic group usually results in fission of the molecule but that some cyclic structures may be present. Both unconjugated phenols and phenols with a carbonyl in the α position are formed by the cleavage. The α-carbonyl groups formed are mainly responsible for the change in the ultraviolet spectrum during ethanolysis. The rate of phenol liberation decreases more rapidly than would be expected if only a single structure were reacting. Only about 60% of the *p*-phenoxy groups in ethanol lignin are converted to free phenols by acid-catalyzed ethanolysis. An extensive decrease in oxygen content (0.3–0.6 oxygen atom/guaiacylpropane unit) takes place and is apparently due to independent intramolecular dehydration reactions. The behavior of spruce ethanol lignins on re-ethanolysis is closely analogous to that of guaiacylglycerol β-aryl ethers. [Bul. Pap. Chem. V. 28, No. 2]

The preparation of abstracts from world literature in many languages is so highly specialized and costly that the Forest Products Research Society has no abstracting service of its own. For the abstracts in this issue of the JOURNAL the Society is indebted to the respective abstract journals indicated, from which they have been selected with the kind permission of the editors. Readers wishing information in addition to that given in these abstracts should consult the original articles referred to. Copies or additional information can not be supplied by FPRS or the abstract journal. The journals from which abstracts are published in this issue are as follows:

BRI ABSTRACTS OF BUILDING SCIENCE PUBLICATIONS, published for the use of its members, by the Building Research Institute, National Academy of Sciences—National Research Council, 2101 Constitution Avenue, Washington 25, D. C. Over 70 periodicals are reviewed, plus new books and research reports from industrial, governmental, and academic laboratories and organizations.

BULLETIN OF THE INSTITUTE OF PAPER CHEMISTRY, published monthly at Appleton, Wisconsin by the Institute of Paper Chemistry, subscription price $25 per year. This Bulletin publishes over 3,600 abstracts per year on subjects of interest to manufacturers of pulp, paper, fiberboard and allied products.

CHEMICAL ABSTRACTS, published semimonthly by the American Chemical Society. Executive Office—1155 Sixteenth Street, NW, Washington 6, D. C., subscription price $60 per year plus postage. This abstract journal publishes many thousands of abstracts annually with broad coverage of world literature in the entire field of chemistry and allied subjects.

TECHNICAL BULLETIN OF THE FURNITURE DEVELOPMENT COUNCIL is published bimonthly by the Counsil at 11 Adelphi Terrace, London W. C. 2, England. The Technical Bulletin publishes hundreds of abstracts and reviews from world literature annually, relating to the various phases of the furniture manufacturing industry. Subscription price is $5 per year.

The Wide Belt Sanding Machine in Woodworking

Harvey Bennett, Behr–Manning Co., Troy, N. Y. Part of a panel discussion presented at the 11th National Meeting at Buffalo, N. Y., June 23–28, 1957.

One of the most important machinery advances in the woodworking industries in the last few years has been the development of the wide belt sanding machine. Today there are at least three types of wide-belt sanding machines available. It is now possible to process tops, ends, drawer fronts, and in some cases curved stock, in one continuous pass without the need for subsequent sanding operations in the white wood.

A flat-bed sander employing a wide, coated abrasive belt can sand two to four times as fast as any other method. Feed speeds on wide-belt machines range from 30 to 90 fpm as opposed to averages of 15 to 20 fpm on multiple-drum sanders.

With two wide-belt machines arranged in tandem, one operator at the infeed end of the first machine, and another at the outfeed end of the second, the white wood cycle from cutting down to final finish may be completed in one continuous operation at more than twice the speed of older methods. This cycle reduces the annoyance of raised grain, and the fuzziness that occurs when newly sanded wood is exposed to moisture-laden air while in transport from one machine to the next.

A coated abrasive belt of any given merit will out-produce a drum cover because of the cooler cutting action of a belt. Less loading occurs, and the tendency toward grain shedding under high frictional heat is minimized.

The new wide-belt machines require a smaller grit sequence. Wide-belt sanders can achieve the same finsh as a drum sander with only two or three grits as compared with five grits needed for the drum sander.

In comparison with drum sanding followed by stroke sanding, the new wide-belt machines show up very favorably with respect to machine maintenance. Two wide-belt machines will require less time to service than one multiple-drum sander and two stroke sanders.

New developments and refinements by abrasive manufacturers in recent years have been: papers with stronger tensile strength; synthetic abrasives almost diamond hard; and backings, both paper and cloth, that offer greatly increased strength and flexibility, a deterrant to premature breakdown of the backing under severe work-pressure conditions.

These machines and developments and others similar are proving themselves in the achievement of higher production, lower unit cost, lower abrasive costs and more uniform finishing operations, all of which add to the stronger competitive position of the woodworking industries.

Serrations on the rubber-covered feed roll of this Speedfeed sander, plus a rotating brush roll and dust collector, assure accurate contact between the work and the abrasive belt.

Effect of Various Types of Equipment on Sawing Accuracy in Eastern Canadian Hardwoods and Softwoods

G. Brodie Gillies, Gillies Bros. & Co. Ltd. Presented at the 11th National Meeting at Buffalo, N. Y., June 23–28, 1957.

Management is interested in cutting accurate lumber, and usually the standard of thickness or size of boards is left to the individual operator. In the sawmill, three factors play a part in production: the mill building; the carriage, that is the equipment that carries the log being sawn; and the saw.

The mill building must be well built, sturdy and solid. A rickety or quivering building in extreme cases can cause a sixteenth inch or more variation in the lumber, particularly in a timbered mill with the headsaw on a cement base where the building is not firmly tied into it.

The carriage must be properly installed and aligned. Carriage tracks that are out of line, loose, or poorly installed can cause queer-looking boards to come out of a sawmill. The carriage must run back and forth on a line absolutely parallel to the line of cut if the board is to be the same thickness front and back. It must be level at all times. It should maintain precisely the same distance from the line of cut in all positions.

Whether circular, band, or gang saws are used, the same general observations hold true. The saw must be properly installed, aligned, and cared for. The saws should be chosen, sharpened, and run at the correct lineal speed for the type of timber being sawn. The log must be fed into the saw at the correct, steady feed rate to coordinate all the above mentioned items, some of which affect the volume of production more than the accuracy.

Slackness, looseness, or play cannot be allowed anywhere in the chaintrack to wheels, wheels to axles, axles to frame, skids to knees, or knees to setworks.

If boards are uniform but of different thickness, it is usually due to some trouble in the setworks. If boards are wavy, it could be the saw. Sometimes a carriage will throw off a wrong board and will lead to finding a worn spot in the pawls or ratchet at a commonly used position. The last board sawn left against the knees can indicate whether the knees are in line, whether they are perpendicular, whether the saw is vertical, and whether the dogs are holding property against the knees.

All equipment should be chosen to suit the type of mill. Setworks should be chosen to suit the use, and should have practically zero tolerance because any looseness and backslash through the set shaft, knees, carriage frame, axles, and wheels must be added to its tolerance. A cause of much inaccuracy is bark falling on the skids and knees. It is also difficult to get rid of. The only solution is, of course, to bark the logs.

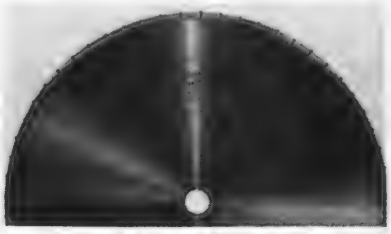
There is a trend towards the use of riderless carriages. Expericene at Gillies Bros. has shown that they produce a much more consistent product with less maintenance. As regards saw care and speed, a poorly filed saw will not cut good lumber. A good filer is necessary to a large production mill, and is also important to the smaller mill. The ideal situation is to have the log hit the saw and maintain an even rate of speed through the cut. The steam, or shotgun, is the trickiest to control, and can cause variation. The electric and hydraulic feeds remove the variation encountered in the shotgun. Theoretically, the newer feeds with a controlled acceleration and a flat terminal velocity should cut the best lumber.

FPRS News-Digest, Continued

Woodworking Machinery Show

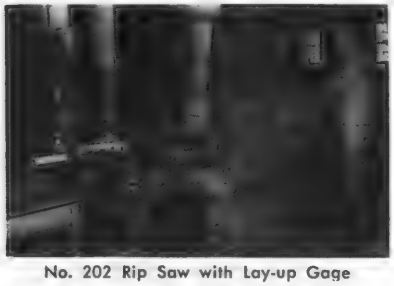
(Continued from page 15-A)

Length of service is reported as unusually long. Other products such as carbide knives and diamond jointing stones will also be demonstrated.

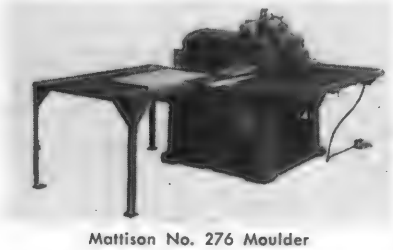


Lemmon & Snoap Gulletless Saw

Two new machines, one, an Automatic Shaping Lathe, and the second, a pedastal-type Cutterhead Grinder with ball bearing table, will be shown by Mattison Machine Works, Rockford, Ill. Also to be shown are the No. 276 Moulder with tapered spindles, and the No. 202 fast feed Straight Line Rip Saw with panel lay-up-gage. The lay-up gage can be operated at either the right or left hand side of the saw blade, either manually or by remote control, through a foot switch and air cylinder.



No. 202 Rip Saw with Lay-up Gage



Mattison No. 276 Moulder

A system of sawyer control will be exhibited by Mill Equipment, Inc., Seattle, Wash. In the Selectric system, the conventional setter-operated carriage setworks is replaced by a remote-controlled sawyer-operated setworks that derives its power from a constantly running electric motor mounted on the carriage. The firm will also show a Heavy Duty Setworks with backstand dial and optional board rule dial, and models of the Selectric push-button selector Switch Control.

Mill Equipment Co. Selectric Sawyer Control

Mill Equipment Heavy duty setworks with Backstand dial

Timesaver Sanders, Robbinsdale, Minn., will exhibit its newest abrasive sanding machine, the Speedbelt 12. The machine can be utilized in production line set-ups, or for hand feeding of small wood parts such as chair arms, legs, drawer fronts, and so forth. Also to be shown is the Timesaver Speedbelt Sander TOP-24, which has automatic air-controlled belt tracking.

Timesaver Speedbelt 12

In addition to carbide tipped Gang Rip Saw blades, Victory Carbide Saw & Tool Co., Inc., Chicago, Ill., will display stickers, shapers, moulders, cutters, straight and formed, and router bits.

Victory Gang Rip Saw Blade

You can't shut out CANCER this way

FEAR AND DELAY are the two most potent allies of cancer. Too many Americans *needlessly* lose their lives to cancer . . . because they put off going to their doctors.

Many cancers are curable if treated *in time*. Even 15 years ago, medical science was saving 1 out of 4 cancer patients. Today, it's saving 1 in 3. The odds would be even better if people would have a health checkup annually and be alert to cancer's seven danger signals:

1. Unusual bleeding or discharge. 2. A lump or thickening in the breast or elsewhere. 3. A sore that does not heal. 4. Change in bowel or bladder habits. 5. Hoarseness or cough. 6. Indigestion or difficulty in swallowing. 7. Change in a wart or mole.

If your signal lasts longer than two weeks, go to your doctor to learn if it means cancer.

Having a health checkup every year is the smart thing to do—a checkup is your best insurance against cancer.

And it's equally smart to send your check to help in the continuing fight against this merciless killer.

Send your check to "Cancer" in care of your local post office.

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Ohio Match Co., Coeur d'Alene

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The Dean Company, Chicago
General Electric, Ill. Cabinet Plant, Rockford
Greenlee Tool Co., Rockford
Edward Hines Lumber Co., Chicago
Johnson & Carlson, Chicago
Masonite Corp., Chicago
Mattison Machine Works, Rockford
Sherwin-Williams Co., Chicago

INDIANA
The Dunbar Furniture Mfg. Co., Berne
National Homes Corp., Lafayette

KENTUCKY
Deluxe Saw & Tool Company, Louisville

MAINE
Moose Head Mfg. Co., Monson

MARYLAND
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Atlas Plywood Corp., Boston
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A. G. Spalding & Bros., Inc., Chicopee

MICHIGAN
Armstrong Machine Works, Three Rivers
Baker Furniture, Inc., Grand Rapids
The Dow Chemical Co., Midland
Everett Piano Co., South Haven

MINNESOTA
Mereen-Johnson Machine Co., Minneapolis
Minnesota Mining and Mfg. Co., St. Paul
Rilco Laminated Products, Inc., St. Paul
Wabash Screen Door Co., Minneapolis

MISSISSIPPI
Richton Tie and Timber Co., Richton

MISSOURI
Monsanto Chemical Co., St. Louis

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Behr-Manning Corp., Troy, N. Y.
Borden Co., New York
Peter Cooper Corps., Gowanda
The New Jersey Industries, Inc., New York
Oval Wood Dish Corp., Tupper Lake
Pierce & Stevens Chemical Corp., Buffalo
Reichhold Chemicals, Inc., White Plains
United States Plywood Corp., Brewster
The Upson Co., Lockport

OHIO
American Machine & Foundry Co., Shelby
The Baldwin Piano Co., Cincinnati
Coe Manufacturing Company, Painesville
The Kirk & Blum Mfg. Co., Cincinnati

OREGON
Brooks-Scanlon, Inc., Bend
Cascades Plywood Corporation, Lebanon
Conroy Publishing Corp., Portland
Forest Fiber Products Co., Forest Grove
Mater Engineering, Corvallis
McNeils Lumber Co., Portland
Oregon Lumber Co., Baker
West Coast Lumberman's Assn., Portland

PENNSYLVANIA
Kennametal, Inc., Latrobe
Koppers Company, Inc., Pittsburgh
Perkins Glue Co., Lansdale
United States Steel Homes, Inc., Harrisburg
Wood Metals Industries, Inc., Kreamer

SOUTH CAROLINA
Lightsey Brothers, Miley
Poinsett Lumber & Mfg. Co., Pickens

TENNESSEE
E. L. Bruce Co., Memphis
Chapman Chemical Company, Memphis
Memphis Hardwood Flooring Co., Memphis
Nickey Bros., Inc., Memphis

TEXAS
Wm. Cameron & Co., Inc., Waco
Kirby Lumber Corporation, Houston
Love Wood Products of Texas, Diboll
Southern Pine Lumber Co., Diboll

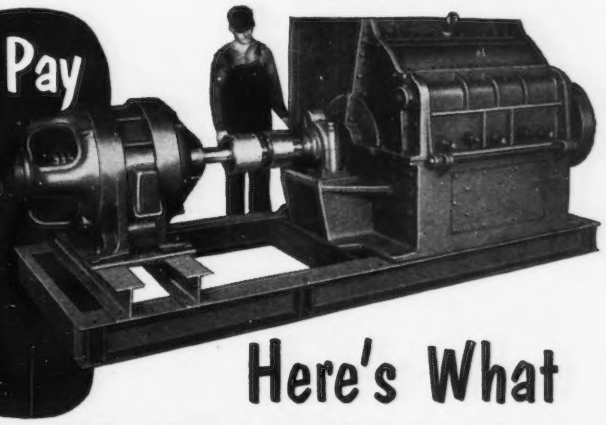
VERMONT
Beecher Falls Mfg. Corp., Beecher Falls

WASHINGTON
American Marietta Co., Seattle
Biles Coleman Lumber Co., Omak
Cascade Lumber Co., Yakima
Chelan Box & Mfg. Co., Chelan
Columbia Plywood Co., Inc., Seattle
Diamond Match Co., Spokane
Douglas Fir Plywood Association, Tacoma
International Paper Co., Long-Bell Division, Longview
Simpson Logging Co., Shelton
Sumner Iron Works, Everett
Weyerhaeuser Timber Co., Tacoma

WISCONSIN
Harnischfeger Corp., Port Washington
Mosinee Paper Mills Co., Mosinee
D. J. Murray Mfg. Co., Wausau
Paine Lumber Co., Oshkosh

CANADA
B. C. Forest Products, Ltd., Vancouver
British Columbia Lbr. Mfrs. Assn., Vancouver
Canadian Forest Products Limited, New Westminster, B. C.
Dominion Electrohome Industries, Ltd., Kitchener, Ont.
Knight Mfg. & Lbr. Co., Ltd., Meaford, Ont.
MacMillan & Bloedel Ltd., Nanaimo, B. C.
A. S. Nicholson & Son, Ltd., Burlington, Ont.

It Will Pay You To CHECK These Facts!



Here's What

WILLIAM'S "NO-NIFE" HOGS

Can Do For You:

1. Increase The Heating Value Of Your Wood Scrap!

When reduced to chip form by hogging, wood burns more evenly—gets *all* the heat value possible. Unhogged slabs, trimmings, large pieces, restrict air flow, smother fire, result in inefficient combustion.

2. Improve Quality Of Wood Flour And Sawdust!

Processing wood scrap with a Williams Hog, for resale in the form of wood flour or sawdust, assures more uniform grinding and sizing—much lower labor costs—reduced power requirements.

3. Reduce Handling Cost As Much As 75%!

One man firing wood in chips can handle the same tonnage as would require three men if fuel scrap remained in awkward lengths and pieces that necessitate individual handling.

4. Your Operation May Permit Complete Automatic Handling

Williams has made many automatic installations to hog and convey waste wood to stoker or boiler at tremendous savings in handling expense. Other installations to automatically grind, separate and package wood flour and sawdust result in phenomenal reductions in cost.

Williams equipment will actually pay for itself in a few months, then continue to produce extra profits for many years. Investigate now!

Write for Details

WILLIAMS BUILDS A COMPLETE LINE • Hogging, Grinding & Shredding Machines • Vibrating Screens • Conveying Systems • Air & Mechanical Separators • Complete "Packaged" Plants • Cyclone Collectors

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OLDEST AND LARGEST MANUFACTURER OF HAMMER MILLS IN THE WORLD

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SEE IT AT OUR BOOTH
No. 169 — No. 170
AT THE

AMERICAN WOODWORKING MACHINERY AND EQUIPMENT SHOW

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For information on any type hydraulic hot or cold press, write our Engineering Department.

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Complete Service On Wood Preservatives!

TECHNICAL COUNSEL
A full staff of specialists with years of experience and complete laboratory facilities, ready to assist in every way.

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An experienced engineering department to help in planning, designing and installing new pressure-treating plants; modernizing old plants; selecting equipment to meet your specific needs.

WOODTOX Penta Preservative and Water Repellent
A clear, clean, non-staining treatment combining advantages of Penta plus resistance against swelling, warping, shrinking and other moisture damage. Meets NWMA and Western Pine Assoc. preservative standards.

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Most satisfactory and permanent of all wood preservatives against decay, fungi, termites and other wood boring insects.

NOXTANE SAP STAIN CONTROL
Most effective, safe and economical treatment made for protection against sap stain fungi. Leaves wood bright and clear. Quick solubility, dustless, non-irritating. Won't damage metal equipment.

EQUIPMENT
Exclusive national sales agents for Efurd Machine & Welding Company, builders of Hurricane Debarkers, Peelers, Framers, Incisors, Trams, etc.

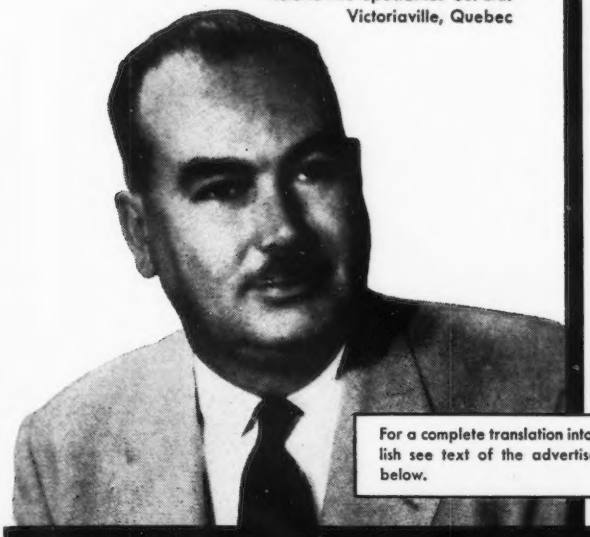
Whatever your problem in the protection and preservation of forest products, this is where you can always get the *right answers quick!* Write or phone.

WOOD TREATING

WOOD TREATING CHEMICALS CO.
5137 Southwest Avenue St. Louis 10, Missouri

"It's always a pleasure to give Mattison machines the recommendation they deserve"

Lucien Arcand, President
Victoriaville Specialties Co. Ltd.
Victoriaville, Quebec



For a complete translation into English see text of the advertisement below.

Victoriaville SPECIALTIES CO. LTD.

MANUFACTURIER DE MEUBLES - FURNITURE MANUFACTURERS
VICTORIAVILLE QUEBEC

Le 6 novembre 195"

M. Phil Mattison,
Mattison Machine Works,
Rockford, Illinois, U.S.A.

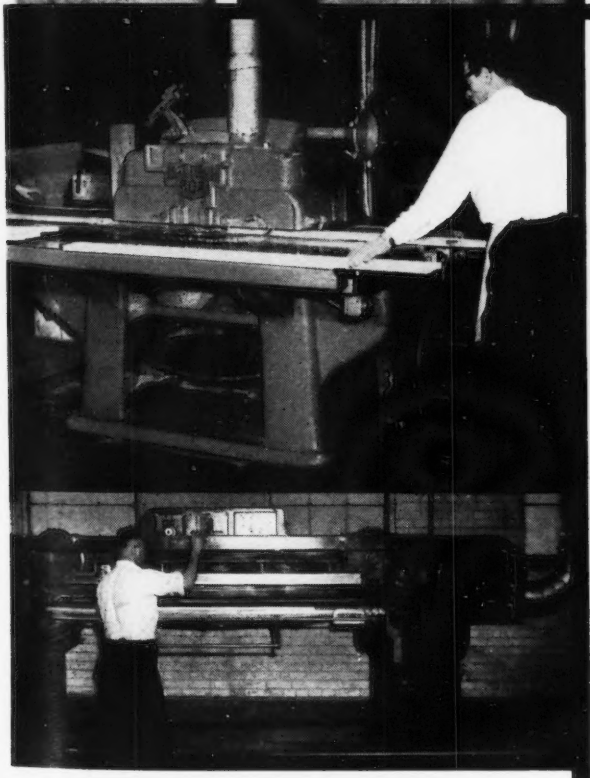
Cher Monsieur Mattison,

Depuis ces quelques dernières années, j'ai reçu maintes demandes d'information provenant de manufacturiers de meuble et autres, relativement aux produits Mattison et, bien que je me sois toujours fait un plaisir de les recommander chaleureusement --honneur au mérite-- j'en suis venu à la conclusion qu'il serait peut être propice de dire au Manufacturier de ces produits combien nous, à Victoriaville Specialties Co. Ltd., estimons la qualité de toute la machinerie qui porte votre nom.

Au dire de ceux qui sont en position de le prouver, au sein de notre organisation, les produits Mattison sont des plus économiques d'opération ainsi que d'efficacité remarquable. De plus, ils sont d'une endurance surprenante.

J'ajoute que l'épargne réalisée, de matériel et de temps, est très considérable, particulièrement en ce qui a trait à l'usage de la Sableuse Automatique #303 ainsi qu'à la Scie à Refendre #202. Cette dernière, dont nous avons été les premiers à nous servir pour faire le joint requis, est de beaucoup supérieure à toutes autres machines du même genre, en usage ici. Elle produit en même temps un joint parfait qui nous exempte cette opération sur la Machine à Joints.

Cordialement vôtre,
L. Arcand
Lucien Arcand, Président,
VICTORIAVILLE SPECIALTIES CO. LTD.



"Over the years," says M. Arcand, president of Victoriaville Specialties, "I have received several inquiries from prospective users of Mattison Products and, while it has always been a pleasure for me to give your products the recommendation they so justly deserve, I thought there would be no harm in letting the manufacturer know exactly how highly we at Victoriaville Specialties Co. Ltd. think of your machinery.

"According to the men who know, within our organization, Mattison products are most economical of operation as well as affording the highest degree of efficiency and endurance.

"Need I add that our savings in material costs, referring particularly to the Mattison #303 Stroke Sander and the #202 Rip Saw, have been quite considerable, especially so with the latter which we were first to put to the test. It produces a clean and true joint, vastly superior to any other machine hitherto in use here."

MATTISON
WOODWORKING MACHINERY

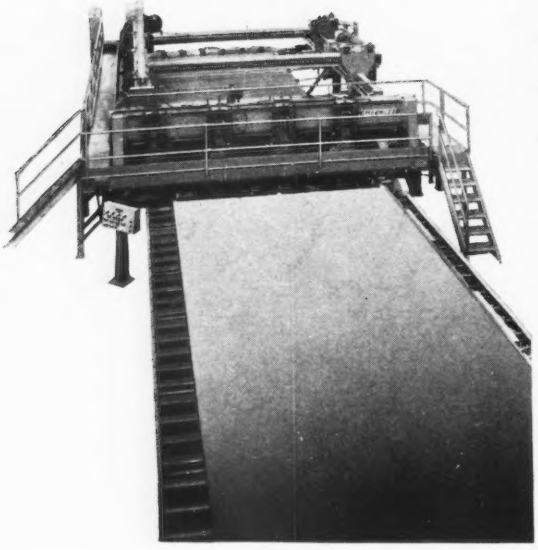
MATTISON MACHINE WORKS
ROCKFORD ILL. U.S.A.

"Built better . . . to produce better quality"

YOU'RE INVITED! At the Winston–Salem Machinery Show, May 13–17, see the Mattison No. 276 Electric Moulder with Tapered Spindles, Mattison No. 202 Fast Feed Ripper with Lay-Up Gauge, new Mattison Automatic Shaping Lathe, and new Pedestal Cutterhead Grinder. See them operate!

GREENLEE SPECIALIZED MACHINES PRODUCE GREATER PROFITS

NEW GREENLEE FIBRE BOARD PANEL MACHINE



- **Handles Panels as Large as 13 ft. x 25 ft.**
- **Splits With Extreme Accuracy**
- **Less Down-Time For Maintenance and Set-Up**

Entirely new in concept and design this Greenlee machine was recently installed in the plant of one of the largest producers of wood and wood fibre products. The first section rips the panel into strips 2 to 4 feet wide; the second, cuts the strips into 2 or 3 pieces as desired. On the first section, feed chain beams are used to transport the stock. On the second, a reciprocating pusher mechanism is employed. All adjustments are made from the overhead catwalks. Each cutting unit is powered by a separate motor. If you have cutting problems involving large panels invite Greenlee to help you solve them. Write today.

Put a Profit in Your Woodworking With Greenlee Machines

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